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76SDS4227

7 May 1976

## EVAL MISSION REQUIREMENTS

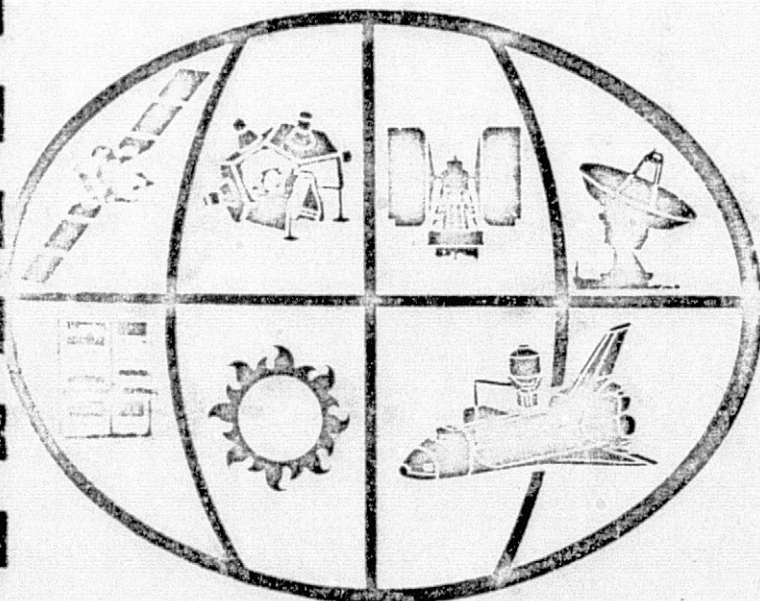
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7 May 1976

## **EVAL MISSION REQUIREMENTS**

**CONTRACT NAS 5-24022**

**Amendment No. 118**

## PREFACE

EVAL is the acronym for NASA's Earth Viewing Application Laboratory. EVAL is a laboratory that utilizes elements of the Space Transportation System (Shuttle and Spacelab) subsystems and software, which when equipped with specific instrumentation, carries out investigations and experiments of interest to NASA's Office of Application and the applications user community. Specific application areas of interest include Earth Resources, Weather and Climate, Communications and Navigation, Earth and Ocean Dynamics, and Environmental Quality/Pollution.

The concept of EVAL involves multiple flights on Shuttle in a variety of Spacelab configurations ranging from a partial pallet to a complete Shuttle/Spacelab payload. In general the EVAL payloads will consist of a majority of fixed, facility-type sensors/equipments which can be used by several disciplines for multiple missions essentially as is, or with minor modifications. These equipments will occasionally be augmented by small complements of special purpose instruments flown for specific experiments.

In the broad sense, EVAL ultimately will encompass studies, hardware, software, facilities, personnel, and data. To optimize the use of EVAL, and in fact, to determine whether EVAL should be developed at all, initial feasibility and concept definition studies are being carried out to match application objectives to EVAL system capabilities, to develop the system, and to determine how it will be implemented and used. The first step in this direction is to determine mission objectives, related experiments/observations, and mission requirements for each of the application disciplines. NASA has already formed discipline Working Groups which are developing this information. Beyond this, studies are required to correlate the discipline Working Groups' requirements and synthesize synergistic payload systems on a "strawman" basis to evaluate basic systems parameters such as pointing, data management, thermal control, contamination, etc. This effort will allow the development of the final EVAL payloads which emerge from subsequent iterations of the mission definitions and the EVAL Working Groups activities.

This Phase I report documents the results of initial data gathered by General Electric on applicable applications missions, experiments, requirements, and sensors; and is intended to be used as input data to the EVAL discipline Working Groups as well as the basis for the preliminary systems studies mentioned above. Mission justification and possible sensor groupings are also included within this report. A detailed sensor catalogue has also been generated as a supplement to this report. In addition, pointing requirements for earth observing missions are analyzed and summarized as a separate report.

## ACKNOWLEDGEMENTS

Appreciation is expressed to the chairmen of the EVAL discipline Working Groups and their panel members who have provided significant inputs with regard to mission definitions, sensor requirements, and mission groupings.

C. Laughlin	-	GSFC	-	Weather and Climate
J. Raper	-	LARC	-	Environmental Quality
R. Moke	-	JSC	-	Earth Resources
J. McGoogan	-	WFC	-	Earth and Ocean Dynamics
E. Wolff	-	GSFC	-	Communications and Navigation

## TABLE OF CONTENTS

Section		Page
1.0	INTRODUCTION .....	1-1
2.0	CONCLUSIONS .....	2-1
3.0	MISSIONS .....	3-1
3.1	Weather and Climate .....	3-1
3.2	Environmental Quality .....	3-16
3.3	Earth Resources .....	3-29
3.4	Earth and Ocean Dynamics .....	3-62
3.5	Communications and Navigation .....	3-82
4.0	MISSION REQUIREMENTS .....	4-1
5.0	SENSORS .....	5-1
6.0	MISSION GROUPING .....	6-1

## GLOSSARY

1. Experiment - A set of activities, i.e., measurements, observations, etc., performed for the purpose of achieving a specific scientific objective or application. The experiment will generally involve the utilization of payload equipment such as sensors and support hardware; but is focused on obtaining data.
2. Payload - A specific complement of instruments, space equipment and support hardware carried to space to accomplish a mission or discrete activity in space. A payload can be reused if brought back to Earth via Shuttle.
3. Mission - The performance of a coherent set of investigations or operations in space to achieve specific program goals. A mission may encompass more than one flight.
4. Cargo - Everything contained in the Shuttle payload bay plus other equipment located elsewhere in the orbiter which is user unique and not carried in the standard baseline orbiter weight budget.
5. Flight - That portion of a mission encompassing the period from launch to landing, or launch to termination of the active life of the experiment. The term Shuttle "flight" means a single Shuttle round trip - its launch, orbital activity, and return. One flight might deliver more than one payload.

SECTION 1  
INTRODUCTION



## SECTION 1

### INTRODUCTION

The objective of this study is to identify what aspects of NASA'S applications mission can be enhanced by utilization of Shuttle/Spacelab, and to define payload groupings which optimize the cost of achieving the mission goals. The approach followed involves the development of preliminary EVAL missions, experiments, sensors, and sensor groupings. This activity is governed by the requirement that the missions must be justifiable, that the experiments are credible and practical for Shuttle/Spacelab, that the sensors are feasible and available for early EVAL missions, and that the sensor groupings embody the low cost features of common equipment and synergistic benefits.

NASA's "Outlook for Space" report was used as the basis for this activity. This report identifies the major technological themes and objectives which NASA will be addressing during the 1980 to 2000 time period. Figure 1-1 provides the complete list of Earth oriented themes and objectives. For the themes and objectives applicable to EVAL (noted in Figure 1-1), specific missions and experiments have been identified as a result of this study. These missions and experiments were developed by GE under the cognizance of the EVAL discipline Working Groups. Reports from the Global Atmospheric Research Program, Total Earth Resources System for the Shuttle Era, and Earth Observation Program provided many of the missions/experiments considered in this study.

Missions/experiments which addressed technique development, sensor development, application development, and/or operational data collection were considered as valid roles for EVAL flights. In technique development early investigations of underlying scientific principles are examined to determine the optimum method for obtaining operational data on subsequent Shuttle or satellite flights. Multi-parameter radar signatures and multi-aspect spectral signatures for various phenomena constitute the major technique developments anticipated on EVAL flights. Sensor development missions provide the engineering checkout required to finalize sensor design for future space missions. Incremental buildup of the sensor can be accommodated and performance verification and calibration accomplished in this mode. EVAL can also be utilized for application development missions in which a proto-type end-to-end applications system is exercised to demonstrate operational potential. Finally, and most importantly, EVAL can serve as an operational platform to perform applications missions and acquire information for operational resource managers. This role can have immediate human impact and be of significant monetary value to the user.

Identification of sensors suitable for the EVAL missions/experiments was accomplished by surveying sensor development offices within NASA and industry, the Advanced Applications Flight Experiments (AAFE), and spacecraft programs such as Skylab, Landsat, Seasat, and Nimbus. Availability for early EVAL flights (1981-1983) was a governing factor; consequently the emphasis was on sensor state of development. Grouping of

EARTH ORIENTED ACTIVITIES RESPONSIVE TO BASIC HUMAN NEEDS:

\* THEME 01: PRODUCTION AND MANAGEMENT OF FOOD AND FORESTRY RESOURCES

- \* Objective 011 - Global Crop Production Forecasting
- \* Objective 012 - Water Availability Forecasting
- \* Objective 013 - Land Use and Environmental Assessment
- \* Objective 014 - Living Marine Resource Assessment
- \* Objective 015 - Timber Inventory
- \* Objective 016 - Rangeland Assessment

\* THEME 02: PREDICTION AND PROTECTION OF THE ENVIRONMENT

- \* Objective 021 - Large Scale Weather Forecasting
- \* Objective 022 - Weather Modification Experiments Support
- \* Objective 023 - Climate Prediction
- \* Objective 024 - Stratospheric Changes and Effects
- \* Objective 025 - Water Quality Monitoring
- \* Objective 026 - Global Marine Weather Forecasting

\* THEME 03: PROTECTION OF LIFE AND PROPERTY

- \* Objective 031 - Local Weather and Severe Storm
- \* Objective 032 - Tropospheric Pollutants Monitoring
- \* Objective 033 - Hazard Forecasting from In-Situ Measurements
- \* Objective 034 - Communication - Navigation
- \* Objective 035 - Earthquake Prediction
- \* Objective 036 - Control of Harmful Insects

\* THEME 04: ENERGY AND MINERAL EXPLORATION

- Objective 041 - Solar Power Stations in Space
- Objective 042 - Power Relay via Satellites
- Objective 043 - Hazardous Waste Disposal in Space
- \* Objective 044 - World Geologic Atlas

\* THEME 05: TRANSFER OF INFORMATION

- \* Objective 051 - Domestic Communications
- \* Objective 052 - Intercontinental Communications
- \* Objective 053 - Personal Communications

THEME 06: USE OF ENVIRONMENT OF SPACE FOR SCIENTIFIC AND COMMERCIAL PURPOSES

- Objective 061 - Basic Physics and Chemistry
- Objective 062 - Materials Science
- Objective 063 - Commercial Inorganic Processing
- Objective 064 - Biological Materials Research and Application
- Objective 065 - Effects of Gravity on Terrestrial Life
- Objective 066 - Living and Working in Space
- Objective 067 - Physiology and Disease Processes

\* THEME 07: EARTH SCIENCE

- \* Objective 071 - Earth's Magnetic Field
- \* Objective 072 - Crustal Dynamics
- \* Objective 073 - Ocean Interior and Dynamics
- Objective 074 - Dynamics and Energetics of Lower Atmosphere
- Objective 075 - Structure, Chemistry, Dynamics and Stratosphere/Mesosphere
- Objective 076 - Ionosphere-Magnetosphere Coupling

\* EVAL Applicable

Figure 1-1. Future Space Objectives - 1980 to 2000

sensors into EVAL instrument clusters was performed on the basis of similar missions, common equipment, synergistic benefits and special requirements such as targets of opportunity and early flights. An attempt was made to combine sensors into facility type complements which can accomplish multiple experiments either within a single discipline or across several disciplines.

The top level relationship of the various elements of this approach are portrayed in Figure 1-2; while the methodology followed in the conduct of this study is portrayed in Figure 1-3.

In this approach two categories of missions are identified for each discipline: The first category represents those missions which are used in this study as drivers for the strawman payloads; (e.g. mission A<sub>11</sub>, A<sub>13</sub>, A<sub>32</sub>, etc.); while the second group consists of additional missions which merit consideration prior to establishing the ultimate operational EVAL payloads. (e.g. missions B<sub>11</sub>, B<sub>21</sub>, etc.). For each mission included in the first category, mission descriptions, mission requirements and sensor descriptions are developed. This data is used as input to an activity directed at identifying potential areas where missions can be combined for synergistic enhancement of user data. Combined mission (e.g. S<sub>1</sub>, S<sub>2</sub>, etc.) are formulated and the sensors associated with each individual mission are carried forward. A matrix is then generated relating sensors to missions. From this matrix, combined missions having overlapping sensor requirements can be observed and a first iteration of possible payload combinations obtained. Since this information may warrant a second look at the synergistic grouping aspects, a feedback loop is accomplished at this point. The sensor groupings which emerge have thus been analyzed from the standpoint of both synergistic benefits and instrument commonality. These groupings are then passed through an accommodation filter based on Spacelab capabilities (nominally for a single pallet) in which weight, volume, view angles, etc. are assessed. Single pallet payloads (G<sub>1</sub>, G<sub>2</sub>, etc.) are then created by combining those S<sub>1</sub>, S<sub>2</sub>, etc. groups having similar orbital requirements, and whose combined resource requirements do not exceed the pallet limitations. Another feedback loop may occur at this point if there are still available pallet resources remaining. In this case an attempt is made to incorporate yet another mission (i.e. A<sub>24</sub>) and its associated sensors) into the payload.

The final study output is a summary of candidate single pallet payloads with their associated mission and sensors. Combined values for parameters such as power, weight, data, pointing, etc. are listed.

The results of this approach provides realistic strawman EVAL sensor groupings which can be used in subsequent payload developments. The benefits of synergistic missions and the use of common instruments for multiple missions are also indicated.

The following sections describe the various missions, sensors, and groupings which have evolved to date. (It should be noted again that these study outputs are preliminary in nature, and will be subjected to future iterations based on inputs from the EVAL

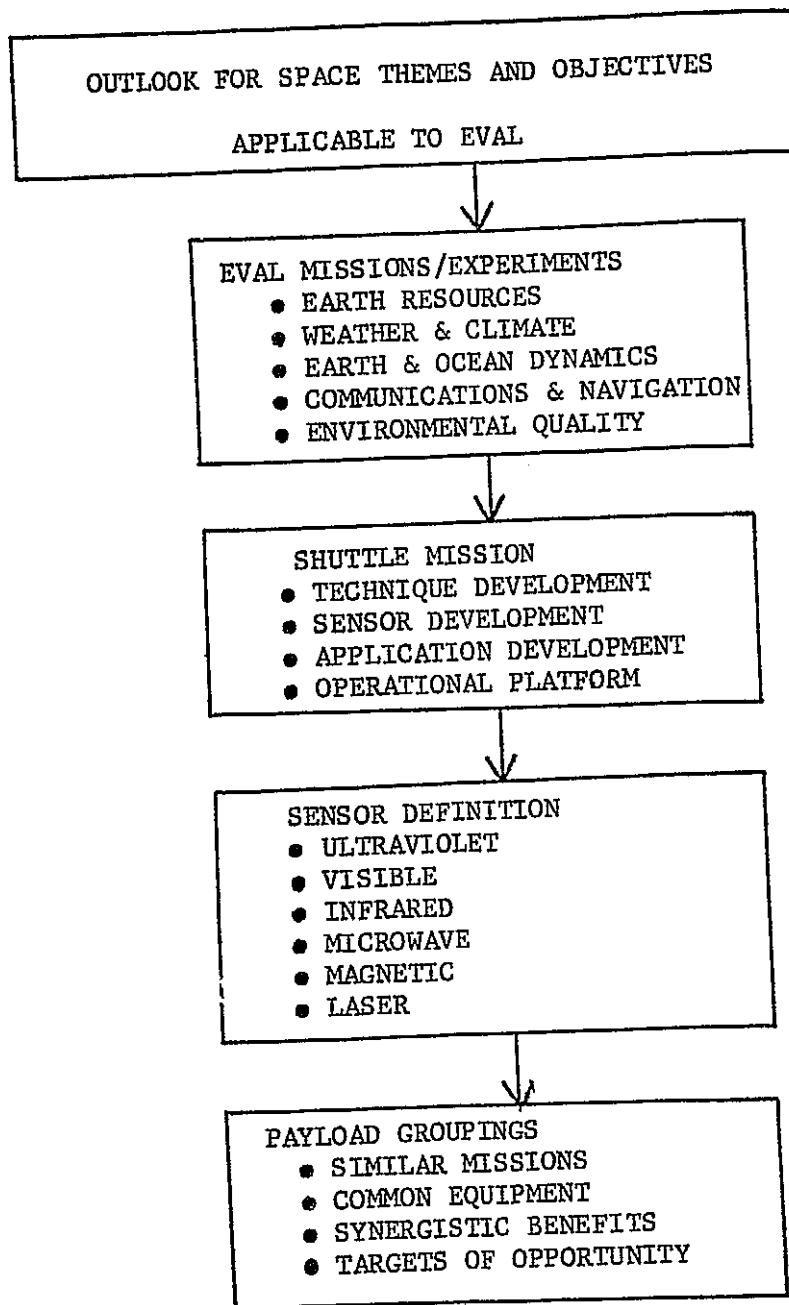
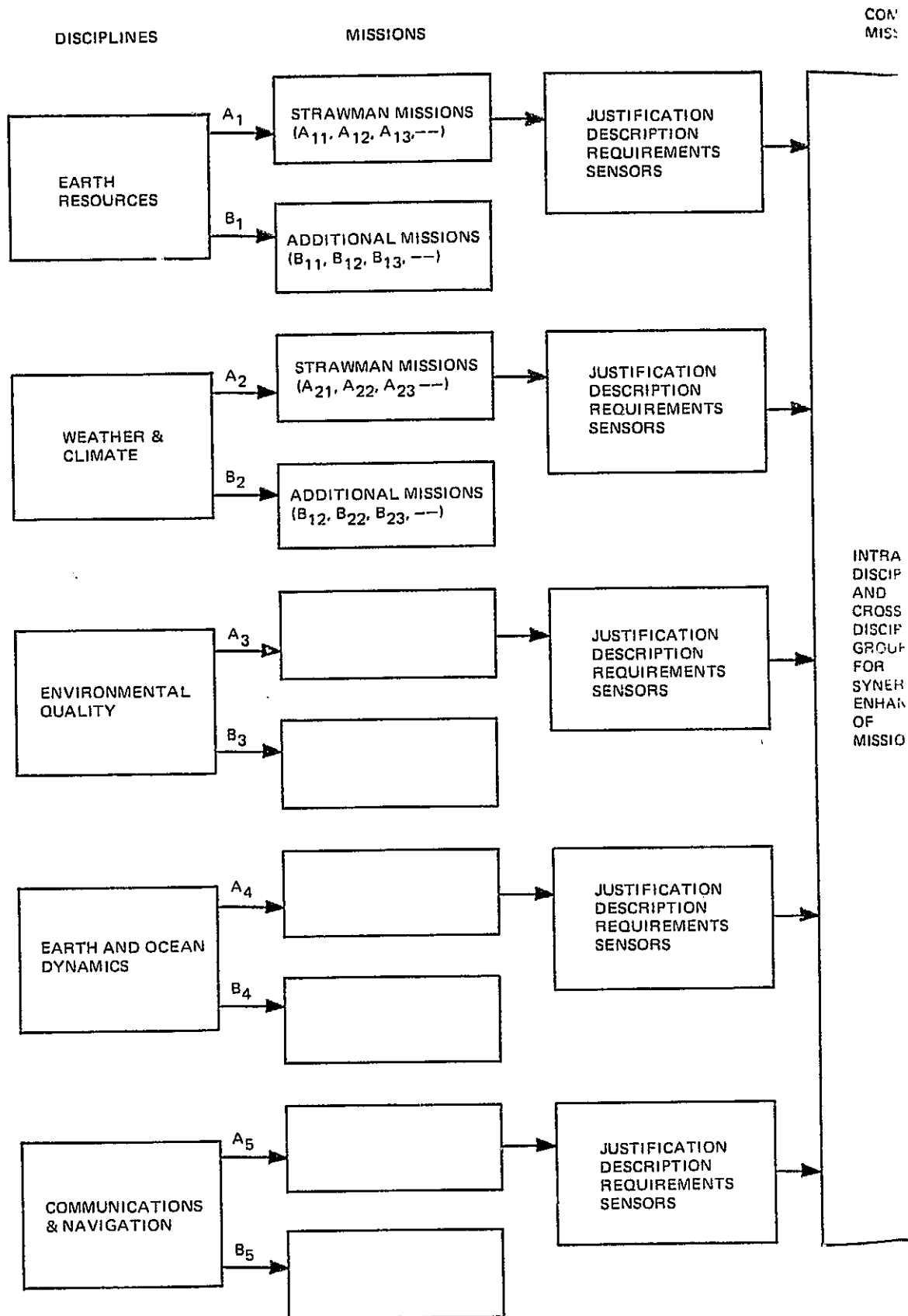


Figure 1-2. Study Approach

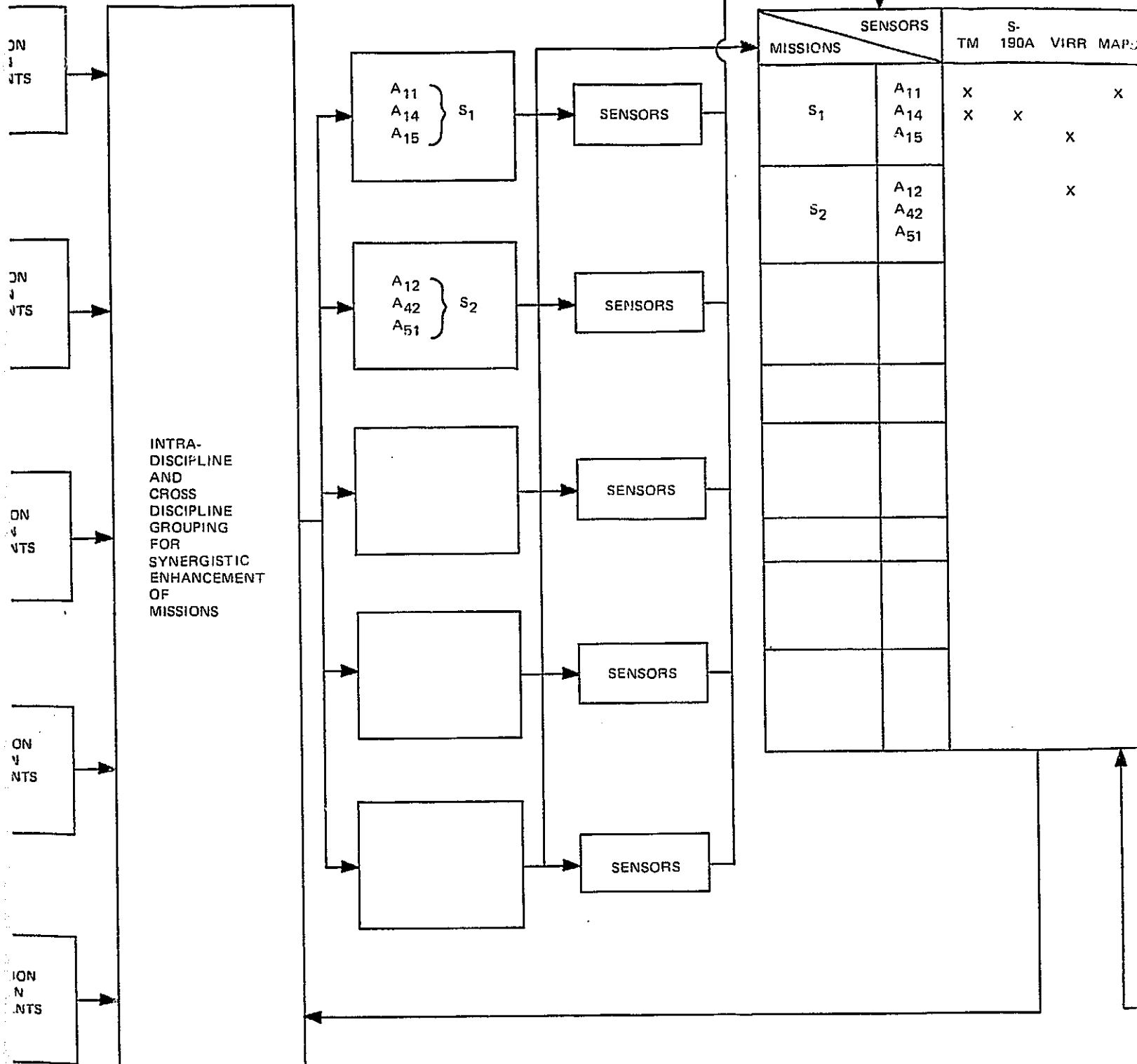


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# COMBINED MISSIONS

# MISSION/SENSOR MATRIX



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# SENSOR MATRIX

## SPACELAB ACCOMMODATION FILTER

### CANDIDATE SENSOR GROUPINS

TM	S-190A	VIRR	MAPS	EEE
----	--------	------	------	-----

X			X	
X	X			
		X		
		X		
				X
				X

- WEIGHT
- VOLUME
- POWER
- 
- 
- 

			WT	PWR	VOL DATA
G <sub>1</sub>	S <sub>1</sub>	SENSOR A SENSOR D SENSOR E SENSOR L SENSOR R SENSOR T			
	S <sub>2</sub>	TOTAL			
G <sub>2</sub>					

SUMMARY  
(SYNERGISM &  
COMMONALITY)

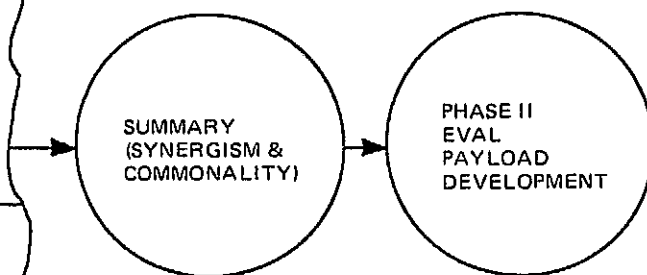
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Figure 1-3. Study M

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# CANDIDATE SENSOR GROUPINS

		WT	PWR	VOL	DATA
S <sub>1</sub>	SENSOR A				
	SENSOR D				
	SENSOR E				
	SENSOR L				
S <sub>2</sub>	SENSOR R				
	SENSOR T				
	TOTAL				



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Figure 1-3. Study Methodology



discipline Working Groups.) The section on missions is segmented by discipline (i.e. Earth Resources, Communication and Navigation, etc.) for convenience and continuity. Significant overlap of missions emerging from the individual disciplines will be noted; however, this is accommodated in the sensor groupings. The section on sensor/instrument definitions combines the requirements of all disciplines to avoid repetition; since the same sensor is frequently specified for multiple missions in more than one discipline. The Sensor groupings section is essentially unconstrained in that some groupings will pertain to single disciplines; while others will be multi-disciplinary.

SECTION 2  
CONCLUSIONS

## SECTION 2

### CONCLUSIONS

There are a few specific missions for which Shuttle is the best platform for the operational application. Timber surveys, census missions, and crustal motion monitoring are examples of such missions.

There are many missions for which Shuttle can play an important role as a platform for technique development. In this mode the principal emphasis is on optimizing the system for a later free-flyer mission; however, operational data may also be obtained. Examples of such missions include the Electromagnetic Environment Experiment, World Crop Survey, Tropospheric and Stratospheric Pollution, and Cloud Climatology.

Sensor development is also a valid mission for which Shuttle is frequently the best platform. This quite often is due to the availability of man, but also arises from the Shuttle's capability to take physically large payloads into space and test them in the zero "g" environment. An example of the former is the development flight test of a Shuttle Lidar, while the Large Deployable Antenna experiment is an example of the latter.

There are many instances in which a single sensor is required for multiple experiments. This occurs both within a specific discipline as well as across several disciplines. For example SIMS, SAR, and the Thematic Mapper are required for various missions in both Earth Resources and Earth and Ocean Dynamics. In this case the same sensor is frequently required for different measurements. In other cases, such as with the SBUV/TOMS which is required for missions in both Weather and Climate and Environmental Quality, the same measurement is used for both disciplines.

Synergistic grouping of experiments and missions is feasible--both within a single discipline and across multiple disciplines. In certain disciplines such as Weather and Climate, Environmental Quality, and Earth Resources, a majority of missions have synergistic associations with other missions within their own discipline - e.g. Tropospheric Trace Constituent Mapping and Stratospheric Pollution; Solar Energy Monitoring and Atmospheric X-Ray Emission; and World Crop Survey with Vegetation Stress and Water Availability Forecasting. Synergistic coupling across disciplines is also realizable with experiments such as Cloud Climatology, Solar Energy Monitoring, and Atmospheric X-Ray Emissions from the Weather and Climate discipline grouped with the Comm-Nav Millimeter Wave Propagation experiment to provide added information on the causes of signal perturbations.

The sensors required for early EVAL missions will be available to support a flight date in the 1981-82 time frame. The majority of these sensors are either being developed for other programs (e.g. Nimbus G, Seasat, etc.) with earlier flight dates or are being actively developed by various NASA program offices.

The majority of instruments being developed for other programs will require some form of modification for the Shuttle missions - resolution, field of view, acoustic and vibration protection are typical modification.

Many of the instruments are physically quite small - especially those associated with Environmental Quality. Consequently, multiple missions can frequently be accommodated on a single Spacelab pallet or less. Conversely, there are a significant number of missions in Earth Resources, Earth and Ocean Dynamics, and Comm-Nav which require very large microwave systems such as the SIMS, SAR, EEE, and Adaptive Multibeam. Accomplishment of missions involving these sensors frequently requires two, and perhaps three, Spacelab pallets.

SECTION 3

MISSIONS

## SECTION 3

### MISSIONS

#### 3.1 WEATHER AND CLIMATE

The selection of weather and climate missions to be considered for the EVAL study was based on several sources of information. The experiments chosen by the NASA/GSFC ad hoc EVAL Weather and Climate working group<sup>1</sup> for a 1981 Spacelab mission formed the major basis for the selection. Other significant sources included the NASA "Outlook for Space"<sup>2</sup> document and the GARP (Stockholm) Report No. 16.<sup>3</sup> Report No. 16.<sup>3</sup>

Based on these sources ten experiments or missions were selected:

1. Ozone Sounding and Mapping/Solar UV Monitoring
2. Cloud Climatology
3. Solar Energy Monitor
4. Atmosphere X-Ray Emission
5. Spaceborne Meteorological Radar
6. Shuttle Scanning Microwave Radiometers
7. Space Shuttle Calibration Facility
8. Stratospheric Aerosols
9. Severe Storm Investigations
10. Weather Modification Monitoring

The first three of these missions were selected as "strawmen" to be considered in detail for determining representative operational, physical and pointing requirements. Selection of these missions does not necessarily indicate relative mission importance, but it does provide a starting point for evaluation of payload configurations.

The reasons for selecting these missions are given below:

1. Ozone Sounding and Mapping/Solar UV Monitoring - The importance of ozone, and its possible depletion, to life on earth is of immediate concern to several government agencies. The shuttle platform provides the capability to periodically calibrate operational ozone monitors on free flyers. The

experiment is essentially developed and is compatible with an early Shuttle flight.

2. Cloud Climatology - The net energy budget of the earth is primarily controlled by clouds. Knowledge of cloud properties is therefore essential to the development of climate models and predictions. The experiment is well documented and is compatible with the Shuttle orbital parameters and will benefit from a repetitive flight schedule.
3. Solar Energy Monitor - The absolute value and spectral distribution of solar energy are essential parameters needed for climate studies. The necessity for periodic monitoring with high accuracy and the ability to retrieve the instrument for post flight calibration make Shuttle a desirable platform.

The following missions would also provide important data to the area of weather and climate but were not considered as strawman drivers for the reasons listed.

1. Atmosphere X-Ray Emission - The data from this experiment is important for improving weather and climate prediction models. The experiment is well documented and its viewing requirements are consistent with the low-inclination orbits of the early Shuttle flights, however, its development status may preclude it from being available for early EVAL flights.
2. Spaceborne Meteorological Radar - The advantages of spaceborne radar over ground based radar in determining vertical profiles of precipitation and liquid water content have not been clearly established. Useful measurements require Shuttle flight over localized storm areas which may have a low probability.
3. Shuttle Scanning Microwave Radiometers - Some of the information obtained from these instruments overlaps that obtained by missions in other disciplines. For example, sea surface temperature is the objective of a strawman mission in the Earth and Ocean Dynamics discipline and thus will provide the necessary radiometer requirements for EVAL payload configuration studies.
4. Space Shuttle Calibration Facility - The instruments selected for the Solar Energy Monitor will form a part of the Shuttle Calibration Facility. Thus, although the goals of the two missions are somewhat different, the required instrumentation is similar.
5. Stratospheric Aerosols - The measurement of aerosol properties is an objective of the Environmental Quality-Stratospheric Pollution mission.
6. Severe Storm Investigations - Further consideration must be given to a mission of this type to assess what useful information can be obtained from Shuttle flight. The main problem is one of probability, i.e., being in the right place at the proper time to detect such localized phenomena as tornadoes or thunderstorms.

7. Weather Modification Monitoring - Objectives and measurement requirements are not sufficiently defined at this time to permit detailed mission tracks and planning.

The objectives, justifications, and descriptions of the "strawman" missions are discussed in the following pages. A summary of the other missions considered is also presented as Table 3-1 at the end of this section.



## MISSION

Title: Upper Atmosphere Ozone, Solar Ultraviolet Radiation  
Monitoring and Studies of the Dynamics Controlling  
Mixing and Transport of Ozone Trace Gases

## OBJECTIVES

It is expected that in the 1980's ozone will be routinely monitored from free flyers (NASA dedicated satellites such as AEM missions or NOAA on TIROS-N) launched bi-annually. The space Shuttle will provide a unique opportunity to:

1. Calibrate ozone monitoring sensors on board free flyers.
2. Monitor the solar ultraviolet output.
3. Survey unique geophysical phenomena not available from free flyers.
4. Evaluate new sensors for ozone measurements.

## JUSTIFICATION

Atmospheric ozone has long been studied because of its importance in the radiative and dynamic properties of the upper atmosphere. The importance of the ozone layer to the biosphere is becoming of increasingly common knowledge because of its possible depletion by trace gases of anthropogenic origin. As stated in the "Outlook For Space":

"One potential problem is a predicted depletion of stratospheric ozone due either to operation of high-altitude aircraft and/or the release of fluorocarbon aerosols into the atmosphere."

The importance of ozone monitoring is also indicated by a publication of the GARP Joint Organizing Committee, The Physical Basis of Climate and Climate Modeling, which stated:

"Stratospheric ozone is important not only as a climatic factor but also is of fundamental importance for life on earth by protecting it from harmful ultraviolet radiation. It is now well recognized that man's activities could influence the distribution of O<sub>3</sub>. Examples of this are continued use of chloro-fluoro-methanes and the injection of NO into the stratosphere by high-flying aircraft. Such effects will complicate the interpretation of future O<sub>3</sub> long-term trends on the time scale of decades."

Because of these potential dangers and the fact that the chemistry and dynamic processes that control the ozone layer are poorly understood, NASA and other government agencies are undertaking studies to determine the present trend in global ozone, understand the fundamental processes for the maintenance of the ozone layer, and to measure the incident solar ultraviolet radiation. With this information, a determination will be made as to the effect of anthropogenic as well as natural sources on the ozone layer. An accurate data base will also provide information to assess climatic trends.

The Nimbus 4, 6 and Atmospheric Explorer-5 satellites carry sensors for the measurement of the vertical distribution and columnar amount of ozone along the sub-satellite track. Nimbus-G will carry additional sensors for ozone monitoring and mapping as well as sensors for measurements of other atmospheric constituents important in the chemistry of ozone.

The natural variability of total global ozone appears to be of the order of only a few percent. The variability due to secular phenomena such as the solar cycle is virtually unknown. The changes due to anthropogenic sources will most likely begin very slowly and possibly be masked by sensor degradation on-board free flyers. Therefore, in addition to the long term commitment, beginning at about 1980, to a monitoring program from free flyers, additional measurements are required to recalibrate these instruments during extended orbital flights and to provide continuity between flight missions.

#### DESCRIPTION:

##### 1. Calibration for Ozone Monitoring

It is proposed to utilize the EVAL platform on a quarterly or semi-annual basis for ozone measurements using a standardized instrument utilizing the backscattered ultraviolet (BUV) technique. This technique makes use of ultraviolet sunlight which is scattered by air molecules, reflected at the surface, and absorbed by ozone. At wavelengths shorter than  $295\text{ m}\mu$ , the scattering occurs at wavelength dependent levels in the atmosphere above 25 km such that the vertical ozone distribution can be inferred. At wavelengths longer than  $310\text{ m}\mu$ , the scattering occurs in the troposphere and at the surface so that the total amount of ozone can be determined. The BUV instrument has been successfully flown on Nimbus-4 and Atmospheric Explorer-5 spacecraft and will be flown on Nimbus-G with an additional capability to map the total ozone.

##### 2. Periodic Monitoring of the Solar Ultraviolet Output

The solar ultraviolet flux incident on the earth's atmosphere is the prime mechanism for the establishment and maintenance of the ozone layer through photo-disassociation of molecular oxygen and ozone. It is also available for the photodisassociation of other trace gases that become catalytic sinks for ozone such as fluorocarbons. The photo-disassociative processes are spectrally dependent as well as dependent on the absolute amount.

Therefore, it is proposed to monitor the solar output at regular intervals for at least one solar cycle. The measurement should be performed with high spectral resolution ( $0.1800-0.2300 \mu\text{m}$ :  $0.0025 \text{ m}\mu$ ;  $0.2300-0.3100 \mu\text{m}$ :  $0.0050 \text{ m}\mu$ ) and with high absolute accuracy (10%). The first measurement can be performed with a modified version of the BUV described above; however, the spectral scanning mechanism is continuous and would extend to wavelengths near  $160 \text{ m}\mu$ . This instrument, the S/BUV, will be flown on Nimbus-G. The S/BUV (Solar/Backscatter Ultraviolet Spectrometer) therefore has two modes of operation; the solar viewing mode with continuous and extended wavelength range and the earth viewing mode for ozone sounding. By continuous access to the S/BUV on shuttle one can determine if any systematic degradation is occurring with the free-flyer version.

### 3. Survey for Unique Geophysical and Anthropogenic Phenomena

The improvement in instrument resolution resulting from the relatively low altitude of the Shuttle orbits will allow more detailed investigation of several phenomena than could be achieved from free flyers. These investigations would include observations of:

1. Tropical cellular features in the high level ozone detected by Nimbus-4.
2. High latitude winter hemisphere ozone enhancements.
3. Effects of local contaminant sources (e.g. volcanoes and stratospheric aircraft operations) on ozone.
4. Detailed structure of the ozone at tropopause breaks and other tropospheric phenomena such as severe storms.
5. Effects of extra-terrestrial energy sources (corpuscular) such as PCA events and energetic photons from electron precipitation.
6. Monitoring Shuttle's own perturbations with time and distance.

### 4. Evaluate New Sensors for Ozone Measurements

Understanding of the dynamics controlling the mixing of the trace gases into the stratosphere and the transport of ozone requires new tools and platforms. The EVAL will offer a new capability to evaluate new sensors and to perform unique geophysical investigations such as those listed above. The measurements could be accomplished by a high resolution 3-D ozone mapper (HROM). Vertical sounding will be accomplished in the normal BUV manner while spatial scanning will be accomplished by a cross track scanner. Design studies are in progress for a scanning technique as well as theoretical studies for formulating algorithms for sounding off-nadir. A total ozone mapper (TOMS) will be flown on Nimbus-G.

Instruments for ozone sounding and solar flux measurements exist. The S/BUV-TOMS for solar spectral irradiance measurements, ozone sounding, and total ozone mapping will be developed for Nimbus-G. The instrument for three-dimensional ozone mapping (HROM) requires additional development that could be accomplished for a 1981 mission if support were provided by FY 1978.

## MISSION

Title: Cloud Climatology Experiment (CCE)

## OBJECTIVE

Following the initiatives of GARP and the needs of present climate modelers, the scientific objectives for the Cloud Climatology Experiment are to gather global statistics of cloud properties to a geographic scale of approximately 200 km and a temporal scale covering both diurnal and seasonal variations.

## JUSTIFICATION

The importance of increasing climate prediction capability is indicated by Outlook For Space Objective 023 - "Determine the Predictability of Climate on Various Time Scales and Develop Seasonal and Longer Period Forecasting Capability." For example, improved ability to predict climate parameters which are relevant to agriculture (e.g. seasonal temperature, length of growing season, precipitation, etc.) would permit planting of grains or grain types which are most compatible with the expected growing conditions.

The observations to be supplied by the Cloud Climatology Experiment (CCE) are expected to be of primary benefit to the discipline of Climatology, especially in assessing the magnitude and variability of cloud radiance properties and how they effect the earth-atmosphere radiative energy budget. The importance of determining global cloud properties was underscored by the GARP Joint Organizing Committee's recent publication, The Physical Basis of Climate and Climate Modelling, which stated:

"There are many short term internal system couplings between atmospheric parameters and radiation, the most important of which is undoubtedly clouds. Clouds reflect and absorb sunlight, and thus decrease the amount of solar radiation reaching the surface. They also absorb and emit terrestrial thermal radiation. As a result, the cloud distribution by type and amount represents a dominant influence in determining the radiation budget of the climate system."

This same document encouraged new instrument development when it recommended:

"The discussion of radiative exchange processes has indicated the need for a refined parameterization of the appearance and disappearance of various forms of extended cloudiness, not generally associated with precipitation, but affecting the radiation budget. In addition to detailed field studies of cloudiness over selected target areas using high spatial resolution images from satellites, aircraft and sonde observations, the need has been expressed for global cloudiness observations to serve as a data base for verifying the performance of cloud modelling and also for empirical refinements of the cloud modelling schemes.

"...New instrument development, such as stereophotogrammetry from a low altitude satellite, polarimetric detections of aerosols and thin cirrus clouds etc. could be envisaged in the future, for implementation on Spacelab or a special purpose radiation budget space platform in nonsynchronous solar orbit."

Thus, detailed knowledge of both the altitude distribution and the composition of clouds is required for climate studies because of the importance of clouds in the radiative energy budget of the atmosphere and in their thermodynamic interactions with the environment. Calculations indicate that the atmospheric state is extremely sensitive to the amount and distribution of clouds. Therefore, the determination of representative cloud physical parameters in addition to altitude represents one of the important links in the development of a complete theory of the general circulation and energetics of the atmosphere. Accurate global observations of cloud distributions will be important not only for the development of comprehensive theories but for subsequent checking of the accuracy of numerical calculations. The CCE data will also be used in albedo calculations and determinations of the solar and thermal flux divergencies of the earth-atmosphere system.

The global observation of clouds can be accomplished most efficiently from an earth orbiting platform. The cloud data must be obtained for both diurnal and seasonal time scales, which requires a multiple flight schedule over several years. These requirements are most consistent with the planned Shuttle orbits and flight schedules as opposed to sun-synchronous satellites. In addition, the cloud climatology experiment is a combined active/passive system which requires a platform capable of providing large amounts of electrical power, supporting large collecting telescopes, and permitting a trained observer to coordinate the use of both instruments. Meeting these requirements with other than Shuttle would require a series or network of free flyers that would not be cost competitive.

#### DESCRIPTION

The observing system is to consist of both an active and a passive instrument. The active system is to be used primarily for optically thin clouds (such as cirrus) and for night-time observations. The passive instrument is designed for observation of clouds of moderate to large optical thickness. Because most clouds are optically thick, this latter system can be used for a large majority of observations. Both systems are scanning and thus will map cloud features along the subsatellite track.

The cloud lidar system (CLS) will operate at both  $0.55 \mu\text{m}$  and  $1.06 \mu\text{m}$ . The transmitted pulse will be polarized and the temporally-resolved backscattered signal will include both the parallel and perpendicular polarization states. This instrument configuration will permit the measurement of the cloud optical thickness and altitude along with thermodynamic phase and particle number density for optically thin or multi-layered clouds.

The Cloud Physics Radiometer, (CPR) will scan spatially and make observations in 8 wavelength intervals in the visible and near-infrared. Because it relies on scattered solar radiation, the near-infrared channels operate only on the sunlit portion of the earth. The radiance collected from both the CPR and the CLS will be used to infer the seven parameters listed below:

1. Cloud Optical Thickness
2. Cloud Top Altitude
3. Cloud Top Thermodynamic Phase
4. Cloud Particle Number Density
5. Cloud Particle Size
6. Cloud Particle Temperature
7. Cloud H<sub>2</sub>O Vapor Content

Of the list of seven parameters, the most important for radiation energy balance studies of the earth's atmosphere are cloud optical thickness and cloud top altitude. Optical thickness is a dimensionless parameter which can be used directly to determine both the amount of solar energy reflected by the cloud and the amount of infrared energy emitted by the cloud. Cloud top altitude is used both to determine the level in the atmosphere at which the radiation energy exchange takes place and, together with the cloud top temperature, to determine the amount of infrared flux lost to space. The remaining cloud parameters are used to better estimate the rates of energy exchange.

The two system technique is a necessary development based on the shortcomings of the individual instruments and the magnitude of the sampling needed. The passive radiometry requires multiple scattering of the radiation by the cloud. Only clouds of moderate or large optical thickness provide enough multiple scattering to satisfy this constraint. The active lidar produces a usable signal only for clouds of small optical thickness. Clouds of large optical thickness attenuate most of the transmitted radiation and thus the signal becomes comparable to, or less than, the noise of the observing system. On the other hand, thin cirrus clouds cover a large portion of the earth and have been identified as a likely source for climatic variability. Combination of the two systems provides the observing capability covering all cloud types and for either day or night conditions.

The CCE system has completed the series of basic studies needed to define instrument characteristics. These studies date from the 1965 flights of the Cloud Altitude Radiometer on Gemini and high altitude aircraft. The flight model of the 6 channel Cloud Physics Radiometer will be included in an aircraft mission in June 1976. The complete CPR and CLS system has been proposed as an Advanced Applications Flight Experiment for flight in the second quarter of FY 78. This time frame permits design study of the EVAL system starting soon afterward.

## MISSION

Title: UV/VIS/IR Solar Energy Monitor

## OBJECTIVES

The objective of this mission is to measure the solar constant and solar spectral irradiance, and the variability of these parameters. In particular:

1. The solar constant is to be measured with an absolute accuracy of at least 0.5%, with an ultimate accuracy goal of 0.1%. Its possible variations will be measured with considerably higher precision.
2. The solar spectral irradiance will be measured over the wavelength range 0.25 to 4.0  $\mu\text{m}$ , which contains about 99% of the sun's energy. The absolute accuracy will be very close to that of the available radiometric standards and will vary with the wavelength range. Representative figures are 2% from 0.4 to 1.5  $\mu\text{m}$  and 5% at the two extremes.

## JUSTIFICATION

The program for long range monitoring of solar flux, total and spectral, has many far ranging uses. In particular:

1. Meteorological phenomena are obviously closely related to incoming solar flux. Relatively small changes in the solar flux seem to have correlation with terrestrial phenomena such as wind circulation, surface temperature, precipitation, etc.
2. Solar energy conversion is a prime contender for solution to the problem of energy shortage.
3. Earth-atmosphere modeling and long-term studies of weather and climate require knowledge of the solar flux variations.
4. Photochemical processes in the stratosphere are caused by the sun and provide the source and sink mechanisms of atmospheric pollution.
5. Many problems in solar physics such as modeling of the sun's atmosphere and its interior require knowledge of the total and spectral flux.
6. Photosynthesis responsible for food production is dependent on two narrow solar spectral bands.



7. Many Earth viewing channels in NASA satellites use the sun as a calibration source and the uncertainty in the currently accepted values of solar constant/spectrum is a major source of concern.

8. Solar energy input is the first major term in the energy budget of the Earth.

The potential users of solar energy monitoring data therefore include NOAA, USDA, ERDA, NSF, NASA ERPR, and DOT. Some of these users will use this data directly for problems relating to solar energy, while other users will employ the data in a synergistic manner to enhance the understanding of their own data, i.e. investigations involving pollution, weather and climate, earth resources, etc.

Solar energy is the major input parameter for the energy received by the Earth's atmospheric system. Its absolute value, total and spectral, and the possible variations constitute essential parameters in a national climate program. Variations in the VIS/IR ranges, which contain most of the energy, are totally unknown and unexplored.

The importance of solar energy monitoring to weather and climate is brought out in the "Outlook for Space" which stated:

"Before we can assess the anthropogenic effects we must first understand the natural processes which affect climate. The sun is the ultimate force which drives atmospheric circulation; but are there variations in the sun's energy output which are affecting weather and climate?"

Measurements made from balloons and aircraft are not sufficiently accurate since the absorptance due to the intervening atmosphere and the ozone is highly variable. In addition, the degree of accuracy required and the problem of radiation measurement are such that the instruments will need to be calibrated, not only before the flight but also after the flight. Free flyers with nonretrievable packages can be used only if they can be checked periodically against a similar package in a Shuttle. Also, the accuracy of measurements requires the immediate supervision of a scientist; therefore Shuttle is an ideal platform for this experiment.

## DESCRIPTION

The solar energy monitoring mission will measure the total solar radiation and the spectral irradiance from 0.25 to 4.0  $\mu\text{m}$ .

Measurements will be made utilizing EVAL two to three times per year during the 1981 to 1991 time frame so that the variations in the total energy and in the energy over narrow bands can be determined with a high degree of precision. Energy flux variations caused by some of the known cyclic and sporadic changes in the sun will thus be confirmed.

A total radiation detector, prism monochromator, and sun-tracking mechanism constitute the required experiment equipment. Little development effort is required for any of these instruments. There are several candidates for the total radiation detector, the PACRAD or ACR developed by JPL, the ESP developed by Gulton/Eppley, the WWCR (wire wound cone radiometer) of GSFC or a secondary standard like the wire wound thermopile. All instruments have been fully documented.

In making the spectral irradiance measurements, a prism monochromator is preferred to a grating as the dispersing element. Here again, several models are available. Since the objective is to have a small compact instrument which will be readily accepted on all or almost all shuttle missions, a prism of 2.54 cm (one inch) base is used. Models of this have been built for the space simulation chamber at GSFC, and for the U-2 aircraft. A mechanism to track the sun will be required.

#### INTRA-DISCIPLINE GROUPINGS

Possible intra-discipline groupings of Weather and Climate missions are shown in Tables 3-2 and 3-3. In Table 3-2, groupings based on synergistic values are indicated. Table 3-3 illustrates the potential commonality of experiment hardware which exists between the various weather and climate missions. The sensors associated with the missions or experiments listed in the vertical column can be applied to partially fulfill the objectives of the missions listed at the top of the table. For example, the sensor used for the Solar Energy Monitor may also be one of the sensors used in the Shuttle Calibration Facility.

Table 3-1. Additional Weather and Climate Missions

Title	Mission Description	Shuttle Role	Typical Users	Shuttle Justification	Sensors
Atmosphere X-Ray Emission	Solar Induced Atmospheric X-Rays	Operational System	NOAA, NCAR, ERDA, NSF, NASA, EPA	Pointing And Weight, Manned Control, Correlative Sensors	X-Ray Camera
Spaceborne Meteorological Radar	Liquid H <sub>2</sub> O Precipitation Intensity	Application Development	NASA, NCAR U.S. Weather Bureau	High Weight Capability, System Re-flight	Meteorological Radar
Shuttle Scanning Microwave Radiometers	H <sub>2</sub> O Vapor, Temp. Profile, Total Precip., Sea Surface	Operational System	NOAA, NCAR, DOD-Navy, Nimbus-G SMMR Team	Laboratory Type Instruments, Multiple Disciplines at Low Cost	SMMR ESMR 94/183 GHz Scanning Radiometer 3M L-Band Array
Space Shuttle Calibration Facility	Obtain Calibration Standards for Use in Radiometry	Operational System	Scientists Using Remote Sensing in UV/VIS/IR	Facility Will Be Returned to Earth After Reference Standards Are Established	PACRAD, WWCR
Stratospheric Aerosols	Concentration and Optical Properties of Aerosols	Operational System	NOAA, EPA	Increased Resolution, Targets of Opportunity (e.g. Volcanoes)	LACATE SER SAM II SAGE
Severe Storm Investigations	Severe Storm Data Base	Technique Development	NOAA, NCAR	Test Bed to Develop Techniques and Sensors	AASIR
Weather Modification Monitoring	Measure Conditions Prior to, Experiment Activity	Operational Support	NOAA, USDA DOT	High Resolution, Man In-The-Loop	ESMR

Table 3-2. Synergistic Grouping of Intra-Discipline Missions

Mission \ Synergistic Area	Weather	Climate	Ozone
*Solar Energy Monitor	X	X #	X
Atmosphere X-Ray Emission	X		X
*Cloud Climatology	X	X #	
*Ozone Sounding and Mapping		X	X #
Severe Storm Investigations	X		
Shuttle Calibration Facility	X	X #	X
Shuttle Scanning Microwave Radiometers	X	X #	
Spaceborne Meteorological Radar	X		
Stratospheric Aerosols		X	
Weather Modification Monitoring	X		

\*Strawman Missions

#Primary

Table 3-3. Instrument Commonality

	Solar Energy Monitor	Atmosphere X-Ray Emission	Cloud Climatology	Ozone Sounding and Mapping	Severe Storm Investigations	Shuttle Calibration Facility	Shuttle Scanning Microwave Radiometers	Spaceborne Meteorological Radar	Stratospheric Aerosols	Weather Modification Monitoring
Solar Energy Monitor	•					X				
Atmosphere X-Ray Emission		•								
Cloud Climatology			•		X				X	X
Ozone Sounding and Mapping				•						
Severe Storm Investigations			X		•					
Shuttle Calibration Facility	X					•				
Shuttle Scanning Microwave Radiometers			X		X		•			X
Spaceborne Meteorological Radar			X		X			•		X
Stratospheric Aerosols				X					•	
Weather Modification Monitoring			X		X					•

### 3.2 ENVIRONMENTAL QUALITY

The experiments selected for EVAL missions in the area of environmental quality were sub-classified into the following spatial regimes:

1. Stratosphere
2. Troposphere
3. Water

Within the three categories a number of problem areas were outlined and the following experiments were defined to resolve them:

1. Stratospheric ozone depletion. \*
2. Tropospheric trace constituent mapping.\*
3. Water pollution. \*
4. Atmospheric radiative transfer changes (stratospheric and tropospheric).
5. Stratospheric and tropospheric exchange.
6. Cross calibration of instruments.
7. Urban heat island.
8. Environmental baseline data.
9. Investigation of red tide.
10. Lake eutrophication.

The problem areas were defined by the EVAL Environmental Quality Monitoring Working Group. In general these experiments were also highlighted by the Outlook for Space Study Group report and the report "Practical Application of Space Systems" by the Panel on Environmental Quality to the Space Applications Board of the Assembly of Engineering, National Research Council. A brief justification for each experiment will be given below. The first three missions are then discussed in detail while the remaining missions are summarized in Table 3-4 at the end of this section.

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\*Strawman Missions

1. The question of stratospheric ozone depletion is extremely important in view of the regulating effect which ozone has on the solar ultraviolet flux reaching the earth's surface. Any decrease in the ozone concentration would permit increased levels of solar ultraviolet radiation to reach the earth with a resulting increase in the incidence of skin cancer and increased damage to crops and vegetation. A determination of the important atmospheric constituents and mechanisms in the ozone chemistry may permit regulation of anthropogenic sources of pollutants which are affecting the ozone balance.
2. The hazardous effects of increasing levels of air pollution on human health have been well documented and have led to the passage of laws which set air quality standards. This requires development of tropospheric air monitoring techniques to assess and control the concentration of harmful trace atmospheric constituents, both gases and aerosols. Repetitive mapping of these constituents is necessary on a regional to global scale.
3. Water pollution is important since it affects both human health and the condition of marine life which may be important economically. Federal water quality acts are aimed at controlling or halting the discharge of pollutants into the oceans, lakes, and rivers. While water quality degradation may be local in origin it quickly becomes regional in nature. As a result spacecraft systems are especially suitable to evaluate and manage water quality on a broad scale.
4. Changes in radiative transfer characteristics of the atmosphere are of extreme importance since they can cause changes in the spectral radiation flux which reaches the earth's surface and affect the thermal balance of the earth. Even minor changes in the average temperature of the earth can significantly affect crop yields, and change energy consumption. Global weather patterns could be altered in potentially disastrous ways.
5. The problem of stratosphere-troposphere exchange is of importance due to the sensitivity of the stratosphere to the introduction of relatively small amounts of constituents which originate in the troposphere (e.g., the ozone depletion problem). Thus an understanding of the processes by which minor constituents or aerosols may be exchanged between the stratosphere and troposphere may provide insight into the climatic or radiative transfer changes which could occur as the concentrations of the gases and aerosols are changed by the exchange mechanism.
6. In sensor development there is always the question of measurement accuracy to be answered. With remote sensors it may never be possible to adequately simulate a satellite viewing condition for calibration purposes. Thus there may be added confidence in a measurement if two sensors which operate on a different principle can be flown to view the same quantity. If the results do not agree within the required accuracy, then further investigation of the sensors or data analysis techniques is indicated.

7. The urban heat island is a problem of concern on an urban scale since it is due to the thermal emissions, building patterns, and natural inversion patterns associated with the urban environment. The result is in the creation of local thermal anomalies which may cause increases in local oxidant concentrations, and in modified rainfall patterns.
8. In the area of water quality there is a definite lack of a substantial data base relating the parameters which affect water quality with the observable spectral or physical characteristics of the water. There is a need for development of sensors in the visible and infrared spectral regions with high spatial resolution to generate a substantial set of baseline data to properly evaluate these measurement techniques.
9. The red tide is a naturally occurring phenomenon whose cause is not understood and which results in local fish kills. The decaying fish pollute the area and render it useless for recreational purposes. Measurements of the sea water characteristics during development of a red tide condition may discover factors which can be controlled and the condition prevented.
10. Measurement of the factors which affect lake eutrophication are important in order to enable the degree of degradation in water quality to be measured. If detected early, the pollutant input to the lake can be controlled and the process reversed to permit the lake to support sport and commercial fisheries.

## MISSION

Title: Tropospheric Trace Constituent Mapping

## OBJECTIVES

The goals of this mission are broad ranging, and include the following:

1. Determine whether there are changes in the radiative transfer characteristics of the atmosphere caused by changes in the minor atmospheric constituents which may have an impact on the global climate.
2. Identify the environmental constituents and parameters which may lead to inadvertent local weather modification.
3. Measure on a local basis the directly harmful pollutants which may cause damage to human health and welfare, to crops and vegetation, and to property.
4. Provide measurements of atmospheric constituents and physical properties for the development of urban air pollution prediction models.

Baseline data in the lower troposphere for  $\text{CO}$ ,  $\text{CH}_4$ ,  $\text{SO}_2$ ,  $\text{NH}_3$ ,  $\text{N}_2\text{O}$ , and  $\text{O}_3$  is to be acquired for these purposes.

## JUSTIFICATION

### 1. Radiative Transfer Changes

Changes in the radiative transfer characteristics of the atmosphere are of extreme importance since they can cause changes in the spectral flux which reaches the earth's surface and affect the thermal balance of the earth. Even minor changes in the average temperature of the earth can significantly affect crop yields, and change energy consumption. Global weather patterns could also be altered in potentially disastrous ways. To ensure that no harmful effects result from these variable constituents such as carbon dioxide and aerosols which affect the earth's heat balance must be monitored to ensure that there are no long term trends occurring which may be potentially harmful.

### 2. Weather Modification

Inadvertent weather modification is a local phenomenon which may occur in the vicinity of urban areas due to urban aerosol generation and increased thermal emission. Local thermal anomalies may cause local oxidant concentrations and modified rainfall patterns. Shuttle flight observations can provide early diagnostic data in this regard because of its ability to sample many widely separated local areas.



The primary constituents of interest in this problem are the aerosols and the pollutants such as sulphur dioxide and ammonia which lead to the formation of aerosols.

### 3. Pollutant Mapping

The hazardous effects of increased levels of air pollution brought about by increasing industrialization and urbanization have been well documented and have led to the passage of laws which set air quality standards. These require the development of air monitoring techniques to assess and control the concentrations of harmful pollutants. Repetitive mapping of the pollutant levels on a regional to global scale is necessary if predictive models of pollutant transport are to be formulated, or if regional sources and sinks for pollutants are to be discovered. Measurements of this type are best performed from a space platform because of the large areal coverage required.

The directly harmful pollutants which must be measured are the aerosols, carbon monoxide, sulphur dioxide, the oxides of nitrogen, ozone, ammonia, hydrocarbons, and peroxyacyl nitrates.

### 4. Pollutant Transport Models

The development of predictive models which integrate pollution measurement, weather and topographic data in an attempt to forecast pollutant levels can aid in the short term management of pollution crises. These models could also assist in environmental impact studies relating to the optimum siting of polluting activities as well as assisting in the identification of local pollution sources.

The specific inputs to the model development would be the vertical concentration profiles for the directly harmful pollutants as well as simultaneous measurements of the local meteorology. Satellite measurements would prove useful in deriving large scale regional models but probably would not provide sufficiently fine spatial resolution for local urban models. Lower orbit Shuttle flights may be able to obtain this resolution.

Tropospheric mapping requires a spaceborne platform to perform sensor measurements which penetrate the total atmosphere on a global basis. The Shuttle role in this overall mission is one of serving as a test bed for early sensor and technique development; while providing a baseline of scientific data which is necessary for the planning of an operational system. Interested users consists of EPA, NOAA, and CEQ.

### DESCRIPTION

The mission objectives will be satisfied by the integration of the following sensors:

1. CIMATS - Correlation Interferometric Measurement of Atmospheric Trace Species.

2. MAPS - Monitoring Air Pollution from Satellites

3. HSI - High Speed Interferometer

The CIMATS and MAPS sensors provide measurements of the total burden of the atmospheric species in the vertical path. The HSI provides a high resolution spectrum of the radiation from the earth and atmosphere in the 2 to 20 micron spectral band.

The measurement capabilities are the following:

<u>SENSOR</u>	<u>CONSTITUENTS</u>
1. CIMATS	CO, CH <sub>4</sub> , H <sub>2</sub> O, SO <sub>2</sub> , N <sub>2</sub> O, NH <sub>3</sub> , O <sub>3</sub> , and any species in the spectral regions 2 to 2.4 $\mu$ m and 4 to 9 $\mu$ m.
2. MAPS	CO, CH <sub>4</sub> , HCOH
3. HSI	Potentially all species in 2 to 20 $\mu$ m spectral band.

Data analysis will require measurements of cloud cover and vertical temperature profile from ground level to be made simultaneously with the sensor measurements. For development flights the inclusion of a TV camera to provide pictorial coverage of the ground track would prove useful.

The sensors essentially provide data on the total vertical burden of the measured species. With some atmospheric modelling the burden measurements can be inverted to yield concentration profiles of the species.

The CIMATS sensor is under development with testing to be completed at the end of 1976 — an earlier version (COPE) has been tested on aircraft. MAPS was developed for Nimbus G, but not included in the flight package. An earlier version of this sensor has also been tested on aircraft. A Shuttle model of the HSI is presently under development — an earlier version of this was flown on Concorde.

## MISSION

Title: Stratospheric Environment Quality

## OBJECTIVES

The objectives of the stratospheric environmental quality mission are the following:

1. Determine whether there is a depletion of the stratospheric ozone concentration due to the introduction of man-made pollutants into the stratosphere; and identify the critical constituents.
2. Determine whether there are changes in the radiative transfer characteristics of the atmosphere caused by changes in the minor atmospheric constituents which may have an impact on the global climate.

## JUSTIFICATION

### 1. Stratospheric Ozone Depletion

The earth's ozone layer is extremely important in regulating the solar ultraviolet flux at the earth's surface. Any decrease in the ozone concentration would permit increased levels of solar ultraviolet radiation to reach the earth with a resulting increase in the incidence of skin cancer and increased damage to crops and vegetation. In addition, photochemical reactions at ground level could change the characteristics of the pollutants. It is hypothesized that introduction of oxides of nitrogen from aircraft operating in the stratosphere, hydrogen chloride from solid fuel rockets, or transport of chlorofluoro-carbons into the stratosphere may be the cause for the depletion of the ozone.

### 2. Radiative Transfer Changes

Changes in the radiative transfer characteristics of the atmosphere are of extreme importance since they can cause changes in the spectral flux which reaches the earth's surface and affect the thermal balance of the earth. Even minor changes in the average temperature of the earth can significantly affect crop yields, and change energy consumption. Global weather patterns could also be altered in potentially disastrous ways.

Since the ozone layer is concentrated in the upper stratosphere and has large scale latitudinal variations, a satellite platform offers the best opportunity for studying the ozone depletion problem. The satellite platform allows for the performance of limb absorption and emission measurements on essentially a global basis. These cannot be adequately performed from other platforms. The Shuttle permits sensors which are currently under development for constituent measurements related to ozone chemistry to be flown early enough to aid in both experiment design and sensor development while providing useful baseline science data concerning the ozone depletion mechanism. Principal users of this information include NOAA, DOT, and CEQ.

## DESCRIPTION

The mission objectives are satisfied by the integration of the following sensors:

1. LACATE - Lower Atmosphere Composition and Temperature Experiment
2. HALOE - Halogen Occultation Experiment
3. SER - Solar Extinction Radiometer
4. CIMATS - Correlation Interferometric Measurement of Atmospheric Trace Species.
5. SBUV/TOMS - Solar Backscatter Ultraviolet and Total Ozone Measurement
6. HSI - High Speed Interferometer

LACATE is a limb viewing sensor which measures the atmospheric emission in a number of narrow spectral bands with a resulting inversion of the measurements to yield vertical profiles of atmospheric species. HALOE and SER are both solar looking sensors which scan the earth's atmosphere by measuring the attenuation of solar radiation in a number of narrow spectral bands as the sun's radiation passes through the earth's limb. CIMATS can also scan the earth's atmosphere by viewing the sun and measuring the attenuation of the solar radiation as the optical path passes through the earth's limb. SBUV/TOMS measures the ozone profile and burden by nadir observations of the solar radiation backscattered by the atmosphere; and HSI provides a high resolution spectrum of the radiation from the earth and atmosphere. The sensor measurement capabilities are the following:

<u>SENSOR</u>	<u>CONSTITUENTS</u>
1. LACATE	$O_3$ , $H_2O$ , $NO_2$ , $HNO_3$ , $N_2O$ , $CH_4$ and aerosols
2. HALOE	$HCl$ , $HF$ , $CH_4$ , $H_2O$
3. SER	$O_3$ , $NO_2$ , aerosols
4. CIMATS	$HCl$ , $CH_3Cl$ , $CCL_3F$ , $CCL_2F_2$ , $O_3$ , $NO_2$ , $NO$ , $N_2O$
5. SBUV/TOMS	$O_3$
6. HSI	2-20 $\mu m$

The sensors measure the emission or absorption of the various species integrated over a long atmospheric path which is tangential to the earth at various altitudes in the atmosphere. The data from a number of scans through the atmosphere at different altitudes must then be inverted to yield the vertical profiles of the constituents.

The required sensors are all either under development, or earlier versions have been flown on aircraft.

## MISSION

Title: Water Pollution

## OBJECTIVES

The mission objective is to obtain a set of baseline data regarding the spectral signature of a variety of water conditions as characterized by temperature, turbidity, suspended solids, chlorophyll content, acid wastes, and marine organisms. This data will serve as initial operational indicators of coastal zone pollution while providing an opportunity for sensor and technique development which can be applied to the ultimate operational system involving spacecraft, aircraft, and in-situ measurements.

## JUSTIFICATION

Federal water quality acts are aimed at halting or controlling the discharge of pollutants into the oceans, lakes, and rivers. Specifically, the Federal Water Quality Act of 1972 is aimed at halting the discharge of pollutants and seeks a dramatic upgrading of the quality of continental waters by 1985. Also, the Marine Protection Research, and Sanctuaries Act of 1972 regulates ocean dumping; thus providing specific protection for the offshore marine environment. While water quality degradation may be local in origin it becomes regional within a short time. Oil spills and ship flushings, the dumping of acid wastes, sewage sludge, and dredge spoils, and sewage outfalls must be monitored and controlled since they lead to increased water toxicity and increased alien populations. The results of this type of polluting is a reduction in aquatic life, fish kills, bottom sterilization, and beach pollution. Federal agencies such as EPA, NOAA, CEQ, ONR, and numerous state environmental control offices require this information as the basis for detecting coastal pollution, prosecuting violators, and ensuring the continued health of coastal waters.

Spaceborne systems are especially desirable as observation platforms to detect this type of phenomena because of the large areal extent involved. Shuttle therefore can be used as an interim source for this type of information prior to the existence of an operational satellite system. When an operational satellite system is in existence Shuttle can continue to be used for this mission either as a coflight platform for correlative data, or as a follow-up high resolution mission to detail and expand a satellite observation.

## DESCRIPTION

The mission objectives are satisfied by incorporating one or more multichannel ocean color sensors on an EVAL flight. A Coastal Zone Color Sensor is being developed for Nimbus G while the Multichannel Ocean Color Sensor is presently under evaluation at NASA/LARC. In the event one or both of these sensors is not available, an earlier generation ocean color sensor is available at NASA/GSFC.

Table 3-4. Additional Environmental Quality Missions

Reference Number	Title	Shuttle Role	Description	Typical User	Use of Shuttle	Mission Importance	Mission Maturity	Recommended Sensors
	Atmosphere Radiative Transfer Changes (Stratospheric and Tropospheric)	Science Data and Sensor Development	Monitor Carbon Dioxide, Aerosols, and the Participants in Aerosol Formation ( $\text{SO}_2$ , $\text{NH}_3$ , etc.) on a Global Basis.	EPA, NOAA, CEQ	Provide Early Tests for Sensors Under Development Under Conditions Which Cannot be Duplicated on A/C or Balloons. Overflight of Locations Where Ground Truth is Available	Moderate	Moderate. Some First Generation Sensors Have Been or Will be Flown. Advanced Sensors and Data Analysis and Interpretation Need Development	CIMATS, VRPM, SBUV/TOMS, ERB, LACATE, APP, HALOE, SAM II, SER/SAGE
	Stratospheric and Tropospheric Exchange	Science Data and Sensor Development	Monitor $\text{O}_3$ , $\text{N}_2\text{O}$ , $\text{HCl}$ , $\text{CF}_2\text{Cl}_2$ , $\text{H}_2\text{O}$ , $\text{CH}_4$ , $\text{H}_2\text{SO}_4$ , $\text{SO}_2$ , $\text{HNO}_3$ , Aerosols, Temperature and Winds on a Global Basis	EPA, NOAA, CEQ	Provide Baseline Scientific Data	Moderate	Low. Stratospheric Sensors are Better Developed Than Tropospheric Sensors. Advanced Sensors, Data Analysis and Interpretation Require Development	CIMATS, MAPS, VRPM, APP, SBUV/TOMS, LACATE, HALOE, SAM II, SER/SAGE
	Cross Calibration of Instruments	Science Data and Sensor Development	Fly Sensors Which Measure the Same Constituents Under Identical Viewing Conditions. Provide Baseline Scientific Data	NASA, EPA, NOAA, CEQ	Provide Early Tests for Sensors Under Development with Overflight of Locations Where Ground Truth Data are Available	Low	Moderate. There are a Number of Sensors Being Developed Which Measure the Same Constituents	CIMATS, MAPS, HSI, HALOE, SER/SAGE, LACATE, APP, SAM II
	Urban Heat Island	Science Data and Sensor Development	Monitor Lower Tropospheric Aerosols and Oxidants, Temperatures and Wind Field on a Local Urban Basis	EPA, NOAA, CEQ	Development Flights for Current Sensors to Determine Feasibility	Low	Low. Tropospheric Sensors are in Development. Data Analysis and Interpretation Require Work	CIMATS, VRPM, MAPS
	Investigation of Red Tide	Science Data and Sensor Development	Monitor Sea Water Characteristics Related to Development of the Red Tide	NOAA, ONR	Provide Overflight of Red Tide Areas	Moderate-Low	Moderate. CZCS will be Flown on Nimbus G. Other Sensors are Under Development	MOCS, CZCS, TM, MSS OR NEW HIGH RESOLUTION SENSORS (IR and VISIBLE)
	Lake Eutrophication	Science Data and Sensor Development	Monitor the Water Characteristics Associated with Lake Eutrophication	EPA, NOAA, ONR	Provide Baseline Scientific Data and to Assess the Sensors and Observation Techniques Under Development	Moderate	Low. Some Sensors have been Flown on A/C and CZCS will be Flown on Nimbus G	CZCS, TM, MSS OR NEW HIGH RESOLUTION SENSORS (IR and VISIBLE)
	Environmental Baseline Data	Science Monitor	Monitor the Physical and Optical Characteristics Associated with any of the Water Quality Problems to Provide a Baseline Databank	EPA, NOAA, ONR	Provide Baseline Scientific Data and Assess Sensor Techniques and Measurement Parameters. Overflight of Locations where Ground Truth Measurements are Available	Moderate-High	Low. Some Low Resolution Sensors have been, or will be Flown. Development of High Resolution Sensors is Required	MOCS, CZCS, TM, MSS OR NEW HIGH RESOLUTION SENSORS (IR and VISIBLE)

## INTRA-DISCIPLINE GROUPINGS

Possible intra-discipline groupings of Environmental Quality missions are shown in Tables 3-5 and 3-6. Groupings based on synergistic enhancement are indicated in Table 3-5; while groupings of missions based on at least partial commonality of instruments are shown in Table 3-6.



Table 3-5. Environmental Quality Intradiscipline Synergism

	Stratospheric Ozone Depletion	Tropospheric Trace Constituent Mapping	Water Pollution
Stratospheric Ozone Depletion	X	X	
Tropospheric Trace Constituent Mapping	X	X	X
Water Pollution			X

Table 3-6. Environmental Quality Sensor Commonality

	CIMATS	MAPS	HSI	LACATE	HALOE	SER	SBUV/TOMS	MOCS	CZCS	Variable High Resolution Pushbroom Scanner	Variable High Resolution Infrared Scanner
Stratospheric Ozone Depletion	X		X	X	X	X	X				
Tropospheric Trace Constituent Mapping	X	X	X								
Water Pollution								X	X	X	X

### 3.3 EARTH RESOURCES

NASA's Earth Resources Program for the 1980 to 1990 time period encompasses a variety of goals and objectives having economic benefits and human impact. Aircraft, spacecraft, and Shuttle flights are all a part of the master plan for accomplishing these objectives. With regard to the Shuttle role, the EVAL program provides a unique opportunity for sensor and applications development. Twelve candidate missions have been selected for inclusion in the Earth Resources portion of the EVAL program. These are as follows:

1. Timber Inventory (015)
2. Mineral Exploration (044)
3. Urban and Regional Planning (013)
4. World Crop Survey (011)
5. Range Condition Assessment (016)
6. Vegetation Stress Detection
7. Water Availability Forecasting (012)
8. Living Marine Resources Assessment (014)
9. Synthetic Aperture Radar (SAR) Development
10. Shuttle Imaging Microwave System (SIMS) Development
11. Modular Multispectral Scanner Development
12. High Resolution Camera System Development

A number of these missions are discussed in the NASA report entitled, Outlook for Space. The numbers in parenthesis are those which the OFS report uses to identify the missions.

The twelve candidate missions were selected on the basis of the following criteria:

1. Satisfaction of significant user requirements
2. Potential for yielding substantial economic benefits
3. Early EVAL availability

The sources from which the missions were derived include the Earth Resources Working Group as well as documented studies such as TERSSE, SEOPS, and the Outlook for Space Study Group. Some of these missions have been heavily studied and are reported on in depth. For those that have not been investigated in depth, a mission description and essential parameters are provided.

Of the twelve candidate mission, the first eight pertain to a combination of technique development and operational application. Few of the missions involve the performance of a fully operational function; however, in the case of several of the missions, successful completion will lead to this end. The remaining four involve the development of sensors required for many of the application missions. Many of the missions are closely related to one another in terms of their equipment requirements. There are also a number of instances in which the output of one mission complements that of another. These aspects are discussed at the end of this section.

The objectives of the Earth Resources portion of the Shuttle/EVAL Program are all aimed toward eventual implementation of fully operational systems. Those objectives which are close to achievement are to be fully realized by the program. Those further away from realization are to be approached through sensor and technique development. The twelve candidate missions specifically address the programs and challenges called for in the OFS statements of objectives. These missions all rely on the unique orbit and equipment flexibility offered by the Shuttle/EVAL Program.

The equipment required for the first eight missions (the operational application missions) consists mainly of the development items in the remaining four missions and of supporting peripheral equipment. Thus, sensor development missions are tied indirectly with the operational application missions. However, if any of the development sensors are unavailable for early Shuttle flights, off-the-shelf sensors will be substituted in the applications development missions.

The users of each type of data and the value of this data to the user depend on the specific mission. However, the aspects of each mission implementation on the Shuttle include the following:

1. Large weight and payload capacity
2. Large power and data storage capability
3. Recoverability
4. Manned interaction in orbit
5. Tailored orbits
6. Lower altitude than polar orbits

Subsequent paragraphs present conceptual payload definitions for the twelve candidate missions. The following items are discussed in each of the definitions:

1. Mission objective
2. Specific investigations proposed to be undertaken
3. Investigation requirements and specifications
4. User benefits
5. Shuttle justification

Six additional missions were selected for inclusion in an alternate "station" mode:

1. Marine Navigation Hazard Monitoring
2. Landform and Cover Mapping
3. Impounded Water Supply Inventory
4. Monitoring of Pollution from Mineral Extraction
5. Assessment of Farming Practices
6. Forest Fire Damage/Regrowth Assessment

These missions tend to be at a less mature state of development than the previously mentioned missions, or overlap with missions from other disciplines, and may be considered for later EVAL flights. Summary descriptions of these missions are presented following the candidate mission descriptions.

## MISSION

Title: Timber Inventory

## OBJECTIVES

To investigate the feasibility of using remotely sensed data to survey and monitor forestland, to prepare forecasts of timber production, to classify areas according to their productive status, and to assess the efficiency and ecological soundness of timber production and harvesting operations.

## JUSTIFICATION

Forest inventory is a continuing endeavor as mandated by the McSweeney-McNary Forest Research Act of 1928. This Act directs the Secretary of Agriculture to cooperate with States and other agencies:

"... in making and keeping current a comprehensive survey of the present and prospective requirements for timber and other forest products in the United States, and of timber supplies, including determination of the present and potential productivity of forest land therein, and of such other facts as may be necessary in the determination of ways and means to balance the timber budget of the United States. . . "

The objective of this periodic inventory of the Nation's forest lands is to determine their extent, condition, and volume of timber, and their growth and depletions. This kind of up to date information is essential to the framing of intelligent forest policies and programs. USDA Forest Service regional experiment stations are responsible for conducting forest inventories and publishing summary reports for individual states.

Forest inventory is also important to the private sector of the forest industry for evaluating sources of raw materials and for detecting trends in forest resource availability. The inventory information is useful for long-range planning decisions, and for industrial investment allocation decisions. It is also essential for state governments and private industry in identifying opportunities for economic development of the states based on forest resources.

Any individual or organization that owns, uses, or regulates a particular timber resource has an active interest in the most current information available about that resource, as provided by the periodic forest inventory. Users of forest inventory information can be divided into three major categories:

1. Federal government
2. State and local government
3. Private owners and users

The single largest user of forest inventory information is the USDA-Forest Service. The USFS conducts research on all phases of forest management and utilization, and assists state and private owners in achieving their management goals. Figure 3-1 gives a summary of the major activities of USFS and some recent statistics on various forest resources. Most of the activities listed require a considerable amount of information supplied by the forest inventory.

Other federal agencies such as the Bureau of Land Management and Bureau of Indian Affairs require forest inventory for management of forest lands under their jurisdiction.

Second in line, but not necessarily in importance, are the users on the state and local government level. Their share in ownership of forest land is small, but most of their resources are utilized quite heavily. This requires sound management planning and, therefore, periodic inventory. Forest inventory information is also essential to state and local governments in identifying opportunities for economic development of states or regions based on forest resources.

The last group of users is the private sector of society, and it includes forest-related industries, farmers and non-government owners. Most of the forest land belonging to, or utilized by, wood-producing industries is under intense management. Goals here are to produce the most wood of desirable quality in the shortest possible time. To attain this goal, forest land must be inventoried periodically. In the management of specific tracts of land, the demand is for detailed point-specific information, currently supplied by consulting companies.

Over half of the Nation's forest lands are owned by several million non-industrial private owners — farmers, businessmen, power companies, and numerous other occupational groups. These owners have a wide range of objectives in owning forest lands and, therefore, a varying willingness and capacity to invest funds in the growing of timber. Only a small percentage of these owners consider timber growing as their principal objective. Most of the land owned by this group is in small tracts (74% in holdings of under 2,000 hectares or 5,000 acres). The need for forest inventory in this part of the private sector is not as urgent as it is in the forest industry. However, growing concern about future timber supply might encourage more intensive forestry on private lands and thereby increase the need for forest inventory.

A periodic forest inventory allows forest managers to make evaluations of present and future timber supplies, and to make comparisons with the projected demand for these supplies. Such evaluations are essential to the forecast of supply problems in the wood-using industries and to the necessary changes in forest policies and programs. Forests are a slow growing renewable resource. However the demand for timber is changing rather rapidly. The demand for industrial timber products in the United States increased by about 7% in the past 25 years. Figure 3-2 gives an indication of present and future timber consumption. Even more rapid are the recent changes in demand for recreational uses of forest areas and for management of forest cover

# U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE

NATIONAL FOREST SYSTEM	RESEARCH	COOPERATION
Protection and Management of 187.1 Million Acres	Through Science Products Knowledge and Technology	With
183.0 Million Acres National Forests	for	State and Private Owners on 574 Million Acres
3.8 Million Acres National Grassland	Managing Resources	To
432,517 Acres of Land Utilization Projects, Purchase Units, Research and Experimental Areas and Other	Timber Water Range Wildlife Habitat Recreation	Meet the Needs of an Expanding Population
Of these lands in FY'73 there were: 1.021 Billion Bd Ft of Timber Harvest (under strict regulation)	Protecting Resources	Through
469.7 Million in Receipts (FY'73)	Fire Insect Disease Pollution	Providing Protection
446.8 Million, Timber Sales	Utilizing Wood Resource	Reforestation (13 Million Acres in 1972)
6.2 Million, Grazing Fees	Wood Products Marketing Engineering System	Increasing Forest Yields
6.8 Million, Mineral Receipts	Plus	Utilizing Forest Products
8.7 Million, Recreation Admission User Fees	Resource Surveys and Related Economics	Reducing Wood Waste
114 Million Returned to States	8 Forest and Range Experiment Stations	Conserving Soil and Water
183.9 Million Visitor Days of Recreation Use (CY'73)	1 Forest Products Laboratory	Providing Forest Recreation
84.6 Million Trees Planted	1 Institute of Tropical Forestry	Enhance Natural Beauty
350,321 Acres Reforested by Planting, Seeding, and Natural Regeneration	70 Other Research Locations	Increasing Fish and Wildlife
15 Million Cattle and 1.7 Million Sheep Grazed	325 Research Projects	2 Areas, 7 Regions, and Institutes of Tropical Forestry
13,579 Fires Promptly Controlled	3,700 Individual Studies	Cooperation with 50 States, Puerto Rico, and the Virgin Islands
116,705 Acres Burned	1,112 Scientists	Public Agencies
More than 4 Million Big Game Animals 491,000 Big Game Animals Harvested	1,300 Publications Annually	Community Development
35 Endangered Wildlife Species		Organizations, and Forestry Industry
9 Regions		
155 National Forests*		
19 National Grassland*		
17 Land Utilization Projects*		
12 Nurseries*		
682 Ranger Districts*		

Figure 3-1. Major Activities of the USFS, from What the Forest Service Does, (Oct. 1973)

for watersheds (essential to our growing population). Also, when considering forest lands, one should not overlook the wildlife habitat, and the preservation of scenic values. This so called multiple-use management of forest lands puts additional constraints on traditional timber production and harvest practices, and at the same time elevates the importance of timely and accurate inventory.

A well-conducted inventory should provide basic inputs necessary for appraising the effectiveness of existing forest management programs, and to indicate opportunities for economic development of timber resources. Since timber products make up almost 20% of all industrial raw materials consumed in the United States, the information on our timber situation has far-reaching economic and environmental importance. The timber industry employs millions of workers; many of them in rural areas and cities where timber is the principal support of the local economy. Concern over prospective depletion of non-timber mineral resources in place of wood products also emphasizes the increasing importance of timber to our economy.

Figure 3-3 shows trends in the U.S. import-export balance. The graph indicates that since the early 1900's, our country has been gradually changing from a net exporting country to a net importer. By 1950, the United States was dependent on foreign sources for about 10% of all timber products consumed. It is expected that a more intensive management of our forest land will improve the import-export balance, and therefore improve the overall balance of trade for the U.S.

A fully operational remote sensing program for the Timber Volume Inventory mission for the United States is expected to encompass a variety of remote sensing platforms. These platforms will include; low orbit sun synchronous polar spacecraft (such as Landsat), Space Shuttle sortie flights, high altitude aircraft, and ground based survey teams.

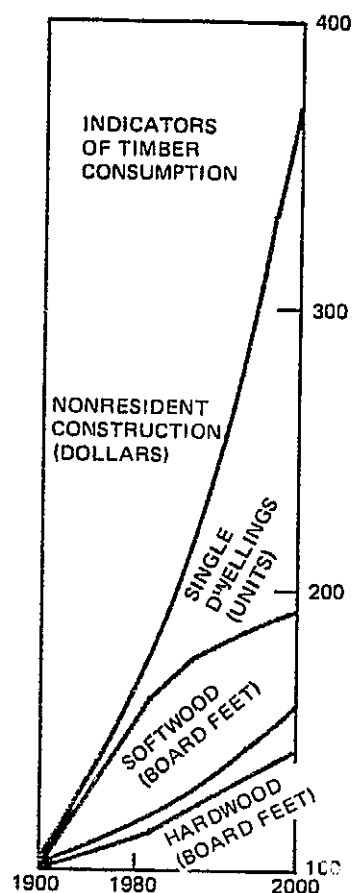


Figure 3-2. Present Timber Consumption and a Projection for the year 2,000

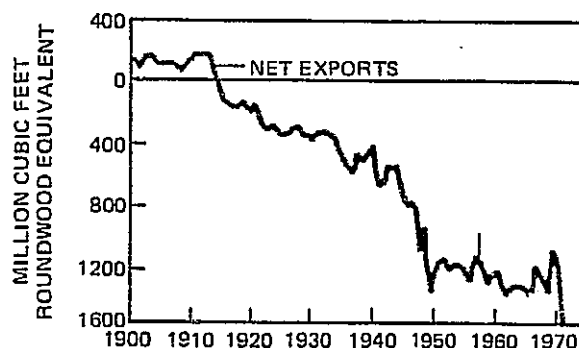


Figure 3-3. U.S. Timber Import-Export Balance (1900-1970)



The Shuttle provides a unique platform for a major element in the Timber Volume Inventory mission because of its ability to carry a comprehensive complement of sensors, including photographic cameras. The Shuttle is, in fact, the only vehicle currently contemplated through the 1980's which provides for the return of photographic film.

Other benefits accruing to the mission which result from incorporation of the Shuttle into the program follow directly from the Shuttle's capabilities:

1. The flexibility for scheduling Shuttle flights and orbits as a function of covered desired.
2. The lower altitude and higher resolution capability of Shuttle sensors than is available on polar spacecraft of the Landsat type.

#### DESCRIPTION

The usefulness of imagery obtained from earth orbiting vehicles in increasing the efficiency and cost effectiveness of forest inventory has been experimentally demonstrated by Landsat investigators. The success of this application is due to the gain in sampling precision obtained in first stage sampling (in a multistage sampling system). In this mission, stands of trees (comprising larger forest units) will be located and boundaries determined as a first stage sampling procedure. Also, parameters necessary for estimation of timber volume per acre will be obtained. These parameters will include the crown diameter and the average crown closure, which are closely related to the tree stem diameter and volume per acre, respectively. Instruments required for this mission include:

1. Modular multispectral scanner or equivalent
2. High resolution camera

## MISSION

Title: Mineral Exploration

## OBJECTIVE

To investigate the use of remotely sensed data for detection of surface indicators of mineral deposits.

## JUSTIFICATION

With an increasing demand for energy and mineral resources brought about by a steadily industrializing world, rapid and cost-effective exploration techniques are required to ensure that raw materials will be available when they are needed. Although the Mineral Exploration Survey mission is really quite broad, it was desirable for this study to constrain the mission scope in order to be able to provide more specific requirements and descriptions. Consequently the mission was founded on copper exploration. When the mission is actually implemented, its scope can be expanded, with little impact to include: other metallic minerals, petrochemicals, geothermal resources and the reconnaissance of geologically active areas.

The rationale for selection of copper exploration as the narrow mission for focusing this study can be summarized as follows:

1. Considered to be a scarce metal resource
2. Strategic/industrial importance
3. U. S. consumption exceeds U. S. production
4. Can be profitable mined from concentrations as low as 0.5%
5. Demonstrated feasibility for remote sensor exploration (both aircraft and satellite).

In as much as the primary goal is to locate new domestic supplies of copper resources, the users of interest are the Federal government and private organizations in the United States.

Foreign users will be discussed only briefly since their exploration requirements are similar to those of domestic users, and since the primary goal of the mission is to provide a measure of mineral resource self sufficiency to the United States. It is anticipated that foreign users will benefit from this mission primarily through the export of copper ore or refined metal from newly discovered domestic reserves, although direct exploration over foreign test sites is feasible and an expanded version (global) of this mission would more directly benefit the foreign users.

It has been reported that 70% of the world's identified copper resources fall into four distinct geologic-geographic groups. In decreasing importance they include the porphyry copper deposits of Chile and Peru, porphyry copper deposits of the southwestern United States, sedimentary copper deposits of Zaire and Zambia, and porphyry and sedimentary copper deposits of the U. S. S. R. Other significant groups include the porphyry copper deposits in Oceania, Mexico and Western Canada, and the porphyry copper and sedimentary copper deposits in southeastern and central Europe. Estimated world wide reserves of copper are shown in Table 3-7. Domestic organizations concerned with the exploration for and development of copper and related mineral resources can be divided into two groups. In the first category are those agencies interested in discovering additional reserves and ensuring an adequate supply for future needs. In the second are those organizations involved in developing the reserves and directly utilizing the metal or selling it to manufacturing industries. The first group includes Federal Agencies such as the Department of the Interior and its functional arms such as the U. S. Geological Survey and U. S. Bureau of Mines, state and regional geologic organizations, and some private companies.

These private companies are comprised mainly of exploration arms of major copper producers and consulting engineering firms who provide mineral exploration service to clients. The second group is comprised of direct producers (of the metal) and manufacturers of various products.

Federal and private users may be related on a contractual basis, where a consulting firm will conduct a specified research program for a federal user. Conversely, a federal agency can encourage private research by providing access to data or through direct financial support (e. g., the Mineral Exploration Assistance Program).

The information derived from Shuttle and supplemental satellite sensors useful to a mineral exploration mission is made available to federal and private users. Federal agencies use the data to compile mineral reports, conduct research, and classify the mineral potential of federal lands. Private users will use the data to locate mineral

Table 3-7. Identified and Hypothetical Copper Resources, in Millions of Short Tons

Area	Identified <sup>1</sup>	Hypothetical <sup>2</sup>
United States:		
Eastern	10	5
Western, Except Alaska	64	75
Alaska	2	20
Canada	19	50
Mexico	18	20
Central America	1	6
Antilles	2	1
South America	80	50
Europe, Excluding U. S. S. R.	25	20
Africa	53	50
U. S. S. R.	39	50
Middle East-South Asia	4	20
China	3	7
Oceania, Including Japan	21	30
Australia	3	3
Total	344	400

<sup>1</sup>Identified resources: Specific, identified mineral deposits that may or may not be evaluated as to extent and grade and whose contained minerals may or may not be profitably recoverable with existing technology and economic conditions. Based on all categories of reserve figures plus estimates where no figures are available. Amounts are tentative and accuracy will be refined in subsequent publications.

<sup>2</sup>Hypothetical resources: Undiscovered mineral deposits, whether of recoverable or subeconomic grade, that are geologically predictable as existing in known districts. Based generally on identified resources figures times a factor assigned according to geologic favorability of the region, extent of geologic mapping, and exploration.

resources either directly (mineral and mining companies) or indirectly (academic research, or interpretations compiled by consultants for clients). In addition to Shuttle and satellite based inputs, conventional information sources, such as the published literature, are utilized. From this interchange and accumulation of data, the final test of a geological survey, namely drilling and sampling at specific locations, can be performed more quickly and with a greater chance of locating workable ore bodies. It is from this process that the primary economic benefit of the mission will be realized.

Use of the Space Shuttle as a remote sensing platform provides several advantages which apply to several different types of missions. Those directly applicable to the Mineral Exploration Survey mission are:

1. The design of the Shuttle mission will complement rather than duplicate measurements which can be made by unmanned Satellites.
2. The Shuttle will be maneuverable, enabling investigators to obtain real-time measurements, and to alter the mission plan as appropriate in the light of data just received.
3. The Shuttle system could provide a selectable real-time observation capability to receiving stations on the ground, via down-link communications channels. When a selected site is approached, real-time monitors in the Shuttle or in the ground station could scan the various imaging sensors and select the most appropriate combination for viewing the scene.
4. The substantial payload capability will enable potential users to enjoy flexibility in employing a wide variety of sophisticated sensors. They will be accessible in flight for adjustment, calibration and repair, and available for post-mission inspection and evaluation.

The Shuttle characteristics will support the mission requirements for greater spatial resolution, stereo photographic coverage, and simultaneous use of different sensor systems. The synoptic regional over-view combined with high resolution imagery permitted by returnable camera systems will enable investigators to pin-point subtle surface features indicative of mineral concentration. Further, the large payload capacity will permit a variety of sensors with adequate power facilities to be utilized. Since this mission is designed to operate primarily over the U. S. , where regional geology has been fairly well defined, the existing regional information can be verified and improved by high resolution images from Shuttle. Acceptable resolution/area coverage trade-offs would be made for the specific missions (e. g. , 3 meter resolution for a 50 x 50 kilometer area, or 20 meter resolution for 150 x 150 kilometer area). Smaller area, higher resolution coverage would be more useful where lineament intersections or rock relationships are of interest. Larger area, lower resolution coverage would be effective for exploring and for locating the surface color changes associated with massive porphyry copper deposits. Whatever the resolution requirements, imagery should be calibrated and metrically correct, in order to facilitate the interpretation of geologic structure, perhaps providing an alternative to computer enhancement techniques.

For camera or scanner sensing systems, true color imagery is important for discriminating lithologies, especially in arid regions. Color infrared imagery is useful for enhancing vegetation and soil types, as well as soil moisture content.

#### DESCRIPTION

The mineral exploration mission will involve a detailed and comprehensive multisensor effort designed to detect geologic evidence of commercial grades and quantities of copper bearing ores (ore being defined as mineral aggregates from which resources can be profitably extracted).

Sensors required for this mission include the following:

1. Synthetic Aperture Radar (SAR)
2. Modular Multispectral Scanner or equivalent
3. High Resolution Stereo Camera

## MISSION

Title: Urban and Regional Planning

## OBJECTIVE

To investigate the feasibility of using remotely sensed data on land use and landform characteristics to support the preparation of legally required comprehensive plans by urban and regional planners.

## JUSTIFICATION

General population growth, accompanied by extensive economic and industrial growth, has placed significant pressures upon finite land resources. Land area equivalent in size to the totals for New Hampshire, Vermont, Massachusetts, and Rhode Island will be consumed by urban encroachment by the year 2000. The "urban field" or "impact zone" will include a third of the area of the U. S. The siting of nuclear power plants, coastal zone development, mineral extraction from near surface, cropland preservation, recreational needs, and wildlife and wildland preservation and management will cause difficult land resource problems. Space system surveys and associated computer techniques could make available to the public, private, and government sectors land resource information in a systematic, timely, and cost-effective manner. The large area involved, coupled with the need for repetitive, uniform measurements, makes the spacecraft superior to the aircraft platform. The aircraft system will continue to be superior for small areas where intensive, one-time study is required for a particular application. Numerous federal and state laws directly or indirectly pose a need for land resource information. Existing estimates of economic benefits range from \$10 to \$115 million per year based on varying assumptions, taking no account for any improvement in the quality of life. (ECON Report).

The user agencies are primarily in the public sector, as opposed to private, although some private land developers and large landowners may also be interested users. The public sector user may be further broken into three categories.

(1) Local level users:

- City and county planning departments

(2) Metropolitan region level users:

- Metropolitan planning agencies (Delaware Valley Regional Planning Commission is a good example)
- Councils of governments (COG's) - these are groups of city and county governments which are formed for the purpose of dealing with area wide problems
- Large county planning agencies - like LA county

(3) Regional level users:

- Special commissions: e. g. , Delaware River Basin Commission, Appalachian Regional Commission, TVA, etc.
- State planning agencies
- Coastal Zone Planning Organization
- Federal agencies such as the Bureau of Reclamation, Corps of Engineers, Bureau of Land Management, etc.

The primary justification for the use of Shuttle as part of this mission is the availability of a cost effective combination of a high resolution photographic camera with medium resolution electronic sensors, providing synoptic coverage of areas of interest due to Space Shuttle. Shuttle not only provides the only visible space platform (through the 1980's) for obtaining synoptic photographic coverage; but, it is also the most cost effective platform (in comparison with high altitude aircraft) for obtaining the volume of photographic data required.

The key factor in the cost effectiveness of the Shuttle is the ability to amortize the cost over several similar users. Most urban and regional planners require the same type of data - just over different locations. Another factor related to the cost effectiveness is the use of "standard" Shuttle sensors which have been proposed for several missions, further amortizing the cost of data acquisition for specific users. Other factors which are unique to the application of the Shuttle to this mission are:

1. Quick response capability for Shuttle flights to aid evaluation of emergency conditions, e. g. , severe floods, hurricane damage
2. Variable orbit characteristics
3. Man available to provide discretionary decisions
4. The ability to use relatively low cost equipment which does not meet the full unmanned spacecraft-reliability criteria.

#### DESCRIPTION

The utility of applying remotely sensed data to the planning activity has been established in several studies (TER SSE, SEOPS). The purpose of this mission is the bridging of the gap between the successful experimental results and a fully operational system, using the Shuttle as a platform to gather higher resolution electronic and photographic imaging simultaneously. Instruments required for this mission include:

1. Modular multispectral scanner or equivalent
2. High resolution Camera.

## MISSION

Title: World Crop Survey

## OBJECTIVE

To investigate the feasibility of using combinations of remotely sensed data to periodically survey crops on a global basis in order to inventory acreage and forecast world production.

## JUSTIFICATION

An accurate global crop production system offers a variety of potential benefits. These benefits are not uniquely humanitarian, but are closely allied with national economic considerations. World food reserves have shrunk from 26% of annual consumption in 1959 to 7% in 1974. North America is the only major exporting region in the world, and food exports are now a major factor in U. S. world trade and balance of payments. Better global crop production forecasting could provide government "food managers" with information pertinent to trade agreements and potential market changes, early warning of crop failures, and data on transportation requirements. Agricultural production could benefit from such information in relation to optimum crops to plant, sell-or-use, harvesting, and storage decisions. Resulting economic benefits as high as hundreds of millions of dollars per year, as well as a stabilizing effect on the commodity market, have been predicted (ECON Report). The Shuttle offers a unique opportunity for development and test of the required sensors and for collection of high resolution data on a global basis from tailored orbits. Table 3-8 lists the potential users of world crop survey data.

## DESCRIPTION

The process of operationally monitoring crops on a global basis will be performed with data gathered from an orbiting satellite. However, this process will be constantly improved and refined. In this regard, the Shuttle/EVAL Program offers an excellent opportunity for sensor parameter evaluation and test data collection for use model evaluation. In addition, the Shuttle offers the opportunity to operationally gather high resolution field sample data on a global basis to increase accuracy and the number of crop production forecasts. Sensors required for this mission are:

1. A modular multispectral scanner or equivalent
2. A Shuttle Imaging Microwave System for soil moisture measurements
3. A high resolution camera.



Federal:	State:	Private Sector:
<ol style="list-style-type: none"> <li>1. Statistical Reporting Service (USDA)</li> <li>2. Agricultural Stabilization and Conservation Service (USDA)</li> <li>3. Economic Research Service (USDA)</li> <li>4. Foreign Agriculture Service (USDA)</li> <li>5. Bell Conservation Service (USDA)</li> <li>6. Animal and Plant Health Inspection Service (USDA)</li> <li>7. Extension Service (USDA)</li> <li>8. Agricultural Marketing Service (USDA)</li> <li>9. Commodity Exchange Authority (USDA)</li> <li>10. Export Marketing Service (USDA)</li> <li>11. Commodity Credit Corp. (USDA)</li> <li>12. Federal Crop Insurance Corp. (USDA)</li> </ol>	<ol style="list-style-type: none"> <li>1. Departments of Agriculture</li> <li>2. Resource development/planning agencies</li> <li>3. Departments of Employment/Human Resources</li> </ol> <p>Local:</p> <ol style="list-style-type: none"> <li>1. County agricultural extension offices</li> <li>2. Water/irrigation districts</li> <li>3. City and county planning departments (sometimes metropolitan, e. g. , DURPC)</li> <li>4. Soil conservation districts</li> </ol> <p>Academic:</p> <ol style="list-style-type: none"> <li>1. Universities (especially state land grant)</li> <li>2. Research organizations</li> </ol>	<ol style="list-style-type: none"> <li>1. Family farms</li> <li>2. Corporate farms</li> <li>3. Commodity storage firms, elevators and warehouses</li> <li>4. Bank Savings and Loan Inst.</li> <li>5. Farm credit organizations</li> <li>6. Farm lobby groups (National Farm Bureau)</li> <li>7. Marketing associations</li> <li>8. Cooperatives</li> <li>9. Food processors</li> <li>10. Wholesalers and retailers, processed commodities managers</li> <li>11. Brokers</li> <li>12. Commodity exchanges</li> </ol>

Table 3-8. Potential U. S. Users of World Crop Survey Data (Continued)

Federal		Private Sector:
<p>13. Bureau of Reclamation (USDA)</p> <p>14. Geological Survey (USDA)</p> <p>15. Bureau of Indian Affairs (USDA)</p> <p>16. Bureau of Sport Fisheries and Wildlife (USDA)</p> <p>17. Corps of Engineers (DOD)</p> <p>18. Dept. of Housing and Urban Development</p> <p>19. Economic Development Administration (DOC)</p> <p>20. Department of State</p> <p>21. Various regional and river basin commissions</p>		<p>13. Transport companies (mainly rail and truck)</p> <p>14. Producers and Distributors of farm machinery</p> <p>15. Producers and Distributors of chemicals (e. g. , pesticides, fertilizer, soil amendments)</p> <p>16. Producers and Distributors of nursery stock</p> <p>17. Insurance companies</p> <p>18. Providers of harvesting service (e. g. , wheat harvesters)</p> <p>19. Exporters/importers of raw and processed commodities</p> <p>20. The media (radio and TV, newspapers, magazines)</p> <p>21. The consumer</p>

## MISSION

Title: Range Condition Assessment

## OBJECTIVE

To investigate the feasibility of using remotely sensed data to survey pasture and range areas to prepare statistical summaries of forage acreages, to calculate supportive capacity for livestock, and to assess current grazing practices.

## JUSTIFICATION

The consumption of beef per capita is growing more than 3% annually, and the increased cost of grain feeding results in increased use of range feeding. Grain fed, commercially slaughtered cattle constituted 80% of the total in 1973 but only 50% in 1975. Continued rises in demand and grain prices result in a need for better range-fed cattle management. It is possible to contribute to this improved management by using spacecraft surveys of the rangeland as a basis for a weekly status report of range conditions. The use of spacecraft data becomes effective in the large areas of the West where grazing conditions are often marginal and the cattle need to be optimally located. Estimated economic benefits derived from this objective range from \$4 to \$30 million annually. (ECON Report)

Specific users of range comparison data include the Forest Service, the Bureau of Land Management, the Bureau of Indian Affairs, state agriculture and natural resource departments and the cattle raising industry.

Shuttle's ability to handle variable size, weight and volume payloads offers a unique opportunity for development and test of the required sensors and for collection of high resolution data from tailored orbits.

## DESCRIPTION

The process of operationally monitoring range conditions will be performed with data gathered from an orbiting satellite. However, the Shuttle/EVAL Program can provide data for evaluation of sensors and techniques. In addition, the Shuttle offers the opportunity to operationally gather high resolution range sample data to increase accuracy and the number of range condition forecasts. Sensors required to accomplish this mission are:

1. A Shuttle imaging microwave system.
2. A modular multispectral scanner or equivalent.

## MISSION

Title: Vegetation Stress Detection

## OBJECTIVE

To investigate the feasibility of using combinations of remotely sensed data to detect and monitor major vegetation stress due to insect infestation, disease, flooding, etc., in U. S. pasture and cropland.

## JUSTIFICATION

Benefits from this program will include improvement of crop production practices, better crop and livestock estimates, more effective control of the spread of crop pests, and better forest and range management. Specific users include the various U. S. D. A. and USDI agencies involved in crop and range management, state agriculture departments, and the total private agriculture and ranching sectors.

Shuttle offers a unique opportunity for development and test of the required sensors because of its substantial capability for payload weight, size and power. In addition, vegetation stress detection and monitoring would require the Shuttle's flexibility in flight and orbit as well as the variable resolution (function of altitude, IFOV) available to Shuttle missions.

## DESCRIPTION

Due to the sporadic nature of vegetation stress, monitoring of this phenomenon over a large area is ideally suited to a Shuttle/sortie type mission. All of the sensors proposed for development - the SAR, the SIMS, the modular multispectral scanner, and the high resolution camera - would be involved in monitoring of vegetation stress due to either insect infestation, disease, flooding, or drought. An example of such a program is the Midwest Corn Blight Watch of 1973. Sensors required for this mission include:

1. Synthetic Aperture Radar (SAR)
2. Shuttle Imaging Microwave System (SIMS)
3. Modular Multispectral Scanner or equivalent
4. High Resolution Camera.

## MISSION

Title: Water Availability Forecasting

## OBJECTIVE

To investigate the use of remotely sensed data to provide forecasts of water availability for irrigation, hydroelectric power generation and shale cracking based on snow and soil moisture and appropriate runoff-prediction models.

## JUSTIFICATION

The world's demand for water has increased markedly in the post-World War II era as population has grown and nations have industrialized. Water consumption in America is expected to increase to 1.25 to 4 times the 1970 level (1480 million cubic meters per day). The primary use of water in the U. S. in the 1990 period is expected to be for electric power, cooling, irrigation, and industrial and municipal needs, in that order (OFS).

On a national level, water availability in the U. S. appears adequate to the end of the century; but large regional insufficiencies are likely. The West will continue to be the most critical water region of the country. Better water availability forecasting can be a significant agricultural and economic factor in these areas. In addition to municipal requirements, the West needs water for irrigation and for efficient hydroelectric generation may also be significantly increased by water requirements due to large scale total demand shale oil processing. A primary water source in the West is the melting of snow which falls in mounting regions. This water is managed by a series of reservoirs. Flood prevention is a major consideration. Current forecasts have errors on the order of 25% (ECON Report). Greater accuracy would result in more water being used for irrigation, power generation, and industry rather than being "dumped". The value of this additional water has been estimated at \$20 to \$50 million per year. Improved measurements for forecasting can come from space system surveys. While directed at a regional need in the U. S., the techniques would be equally useful in other areas of the world which also depend upon mounting snows for water. The extensive mountainous areas, with their associated accessibility problems, plus the need for repetitive observations, make space located instruments an attractive means of forecasting water availability for irrigation, hydroelectric power generation, and shale cracking.

The payload flexibility will enable investigators to develop and employ the sophisticated sensors necessary to this undertaking. The Shuttle's flight flexibility, variable-orbit capability and maneuverability will enable investigators to collect high resolution remote sensing data and in-situ measurements simultaneously.

### DESCRIPTION

The main tasks of this mission are: (1) estimating moisture content for a real extents and (2) development of regional runoff-prediction models. The sensors required for this mission include:

1. Shuttle Imaging Microwave Radiometer
2. Modular Multispectral Scanner or equivalent.

## MISSION

Title: Living Marine Resources Assessment Development Program

## OBJECTIVE

To investigate the use of remotely-sensed data in specifying and monitoring the relationship between marine (environmental and biological) parameters and the habits and characteristics of living marine resources.

## JUSTIFICATION

Living marine resources may contribute substantially to meeting the total food needs of the world. Such resources are important to the food and nutrition requirements of many regions of the world. Estimates of world yield range from near the present yield (70 million metric tons annually) to as much as 30 times the present yield.

With the technology available today, it is impossible to confirm what the real potential increase in productivity from the ocean may be. Therefore, it is difficult to determine how important living marine resources may be to the increasing world food needs. Generally, the increase in productivity would come from more efficient use of presently used species, with some use of new species. A small sample of opinions from government and industry personnel indicated that immediate priority should be placed on the better use and management of presently used species, an increased emphasis on use of new species, followed in turn by an increased emphasis in the development of mariculture techniques.

Comprehensive studies of the cost benefits of a fishery assessment system are not available for coastal species. For oceanic species, however, one study indicates that a 50% reduction in search time for tuna, combined with a 25% increase in catch due to better information, would yield an annual operating cost reduction of \$12 million plus an annual fleet investment cost reduction of \$6.4 million. (Reference 13-OFS Report)

The need for such a system, however, is based on the fragility of the seas as well as their economic contribution to food and protein sources. Examples of fish crop damages or depletion are many: e. g., the disappearance of the Peruvian anchovies, and of the California sardine after World War II; and the destruction of the New England shellfish crop. While it is thought that these failures stem largely from overfishing, the phenomenon is not well understood.

The importance of such a management system is to prevent such localized phenomena and the associated economic perturbations. A modest increase in overall world animal protein supply production might also be expected from this objective, and significant increases in food might be possible in the post-2000 period using mariculture techniques. This objective would help to ensure the perpetuation of living marine resources and provide information on which to base a future mariculture industry.

The Shuttle offers a unique opportunity for development and test of the required sensors and for collection of high resolution multi-sensor data from tailored orbits.

#### DESCRIPTION

This is essentially a research-oriented program. The aim is to attempt to measure marine parameters such as chlorophyll, turbidity, salinity, sea state, etc., to relate these parameters to the habits and characteristics of the various species, and to develop a predictive model based on this correlation. This will be a multi-vehicle investigation, employing unmanned satellites, aircraft, and in-situ measurements, as well as Shuttle data. Sensors required for this mission include:

1. Shuttle Imaging Microwave System
2. Modular Multispectral Scanner or equivalent.



## MISSION

Title: Synthetic Aperture Radar (SAR) Development

## OBJECTIVES

1. To determine the feasibility, utilization, and mechanization of a SAR for a wide range of earth resources Shuttle applications, among which are soil moisture mapping, flood damage assessment, land use surveying and snow cover mapping.
2. To define optimum sensor parameters for the Shuttle and operational use on other spacecraft.

## JUSTIFICATION

The synthetic aperture radar (SAR) is an excellent sensor for orbital application. Since it provides its own illumination over a wide range of wavelengths, for which the atmosphere is essentially transparent, it has a unique day-night and nearly all-weather capability. From the magnitude of the radar return and the range and azimuth coordinates of the scatterers, photograph-like images can be constructed whose resolution are independent of the SAR's altitude. Since the interaction of microwaves with the surface is a function of wavelength among other things, a poly-chromatic radar has the potential of providing information about both the intrinsic properties of the resolved areas as well as their spatial distribution.

Side-looking airborne imaging radars (SLAR), both real and synthetic aperture, have been used successfully for many years in non-military applications. Large files of imagery are available showing a variety of geologic features, sea and lake ice, ocean waves and other large scale features. Much imagery is available which shows that the radar return is a function of soil moisture and vegetation cover as well as surface roughness. Radar has been used for mapping large areas of South America ( $10^7$  square kilometers by 1976 by Goodyear), some for the first time.

There are many potential users of SAR data in geology, meteorology, hydrology, and oceanography (e. g., lake ice measurement, oil spill detection and measurement, flood damage assessment, land use surveying, soil moisture monitoring, soils mappings, petroleum exploration, mineral exploration, snow cover mapping). It is the implementation of these applications for currently unobtainable data which provides the motivation for the sensor development.

The Shuttle offers several unique capabilities when considering a vehicle for an orbital sensor development mission:

1. Large payload capability
2. Large power and data storage capacity

### 3. Recoverability

### 4. Manned interaction on orbit.

Each of these Shuttle capabilities contribute to the SAR development.

The large payload capability enables SAR design without constraining (within reason) the configuration of the hardware, its design state, or weight — providing it meets operating and safety requirements of the flight. As an extreme example it should not be considered undesirable to fly a breadboard configuration during the latter phases of sensor development, if it is suitably packaged to withstand the launch and orbital environment.

Large amounts of available power preclude the need for constraining design with a tight power budget and reduce design/development costs. Once development is complete, suitable packaging can be designed for the specific application.

Recoverability enables early operation of the sensor or its components under the expected (orbit) environment and the circuitry design can be evaluated with preplanned variable input parameters and the results evaluated. Exhaustive and costly ground simulations of the expected environment can be avoided.

With appropriate consideration to the sensor component design and with suitable test/telemetry points available for orbital troubleshooting and repair as necessary, maximum use can be made of the man-in-orbit/machine interface; and substantial savings should result from accomplishment or near accomplishment of the planned orbit objectives. Skylab has shown that, even under extremely difficult conditions, repairs in orbit can be accomplished. With Shuttle, repairs should be significantly easier to perform.

### DESCRIPTION

The intent of this mission is the verification, by flight of prototype hardware, of the design of the SAR as a sensor. The final product is the design specifications for an operational sensor.

The SAR development mission is designed to use the capabilities of the Shuttle as a platform for the further development and flight testing of a SAR hardware design. The mission will consist of initial flights to verify mechanical and electrical integrity of the design, especially the unfurling of a very large (3m x 12m) antenna and the electromagnetic compatibility of the SAR. Subsequent flights will then be used to perform analyses of performance parameters such as sensitivity, spatial resolution, transmitter efficiency, etc., for the sensor. Modifications to the sensors may be made between flights based on analysis of data from earlier flights. The final output from the mission will be a detailed understanding of the requirements and design of operational flight hardware.

The hardware design of the candidate SAR sensor is currently being pursued by both Hughes Aircraft and the Jet Propulsion Laboratory. The Hughes design is for a dual frequency system (X&L band) and employs an all digital technique (clutter tracking) which greatly eases Shuttle attitude control problems in azimuth pointing.

The antenna design allows imaging of a 90 km swath within a 290 km possible illumination range of 20° to 60° off nadir.

Although quite similar to the Hughes design, the JPL design approach incorporates a third frequency (Ku Band - 15 GHz), operated at only one nominal resolution, and requires considerably more power. No definite approach to data recording, handling or preprocessing has been selected, although several trade-offs and comparison have been considered.

Table 3-9 summarizes the salient features of the two designs.

Table 3-9. SAR Sensor Design Summary

	Hughes			JPL
Frequency Plan	X&L Band 9 GHz, 1 GHz			Ku, X, L Band (15 GHz, 1.3 GHz)
Swath Width in View	290 Km			100 km max. 40 km max.
Swath Width Imaged	90 Km	60 Km	30 Km	40 K to 100 Km
Resolution	25 m	12.5m	6 m	25 m
Data Rate	480 Mbps			Unknown
Antenna Size	12 x 3 m, 2 Folds			10 x 3.1 m
Weight	106 Kg			813 Kg
Volume	11.8 m <sup>3</sup>			Unknown
Power	4 Kw			7.8 kw
Polarization	VV and VH HV and HH			VV and VH HV and HH

## MISSION

Title: Shuttle Imaging Microwave System (SIMS) Development

## OBJECTIVE

The objective of the SIMS experiment is to utilize the capabilities of the Space Shuttle to perform passive microwave measurements of thermal emission from the Earth's atmosphere and surface which can be interpreted in terms of meaningful atmospheric and geophysical parameters.

## JUSTIFICATION

SIMS will enable the measurement of the following observables:

- Soil Moisture
- Subsurface phenomena
- Salinity
- Sea surface temperature
- Sea state
- Heavy precipitation
- Atmospheric water vapor
- Moderate and light precipitation
- Drop size parameter
- Storms over land
- Water-ice boundaries

The measurements will be useful for atmospheric oceanographic and earth resources disciplines. Citing a few examples: The improved SIMS resolution will make possible detailed measurements of the dynamics of vapor in hurricane system, which could lead to better understanding and prediction of the formation and evolution of such systems. Atmospheric water can also be mapped over lake areas, which has been unfeasible with the coarser resolution of prior sensors. It will be possible to map sea and lake ice boundaries to 0.5 km resolution, assist in ship routing and partially frozen waters, and study ice circulation in the Arctic. Maps of storm systems over land areas should be provided by simultaneous measurements at 0.57 cm and 0.26 cm wavelengths.

In addition, several of the applications development programs (World Crop Survey and Water Availability Forecast) require SIMS data for their program success.

The unique capabilities of the Shuttle (large payload capability, large power and data storage capability, recoverability, manned interaction) will all contribute to the SIMS development program. The applicability of these unique capabilities for the SIMS program is similar in nature to that for the SAR Program as detailed previously.

#### DESCRIPTION

The SIMS development mission is designed to use the capabilities of the Shuttle as a platform for the further development and flight testing of a SIMS hardware design. Combinations of different frequency bands and resolutions will be employed on successive flights and attempts at correlation with the phenomena of interest will be made. The final output of the mission will be a detailed understanding of the requirements and performance of an operational SIMS hardware system.

##### Equipment Parameters:

Frequency: 11 freq. (610 MHz - 116 GHz)

Resolution: 100 Km (610 MHz) - 1/2 Km (116 GHz)

Antenna Size: 2 m. radius x 2 m

Total Envelope: 5 m diameter x 2 m

## MISSION

Title: Modular Multispectral Scanner Development

## OBJECTIVES

1. To establish the feasibility of a modular/tailorable concept for multispectral scanners to support a wide range of earth resources survey applications.
2. To determine correlations between sensor parameters and earth resources phenomena (e. g. , spectral band limits, bits/pixel, IFOV size, etc. )

## JUSTIFICATION

A multispectral scanner with modularized, easily exchangeable components is necessary for each of the 8 Applications Development Programs proposed for the earth resources area.

The Shuttle is particularly well suited for use in the development of this sensor because of the following reasons:

1. Facilitates return of hardware for modification and servicing
2. Facilitates on-orbit hardware reconfiguration
3. Provides variable lighting conditions.

## DESCRIPTION

The intent of this mission is (1) the provision of an MMS to support Applications Development Programs listed in the preceding sections and (2) the optimization of scanner parameters for each specific application. Combinations of different frequency bands, IFOV sizes, and bits/pixel will be employed on successive flights in order to determine and achieve the optimum parameters for a specific application. In the event that this instrument is not available for early Shuttle flights, however, an off-the-shelf scanner (such as the Landsat-1 MSS) may be substituted.

JSC study design completed/Aerojet design study underway.

## EQUIPMENT PARAMETERS:

1. Spectral bands - 10 (0.45  $\mu$ m - 12.5  $\mu$ m) (6 active)
2. Resolution (max) - 10 m @ 100 n mi

3. Detector type - Linear array (3500 elements/array)
4. Swath -  $22.5^\circ$  (40 n. mi @ 100 n. mi)
5. Data Rate: 240 Mbps
6. Sensitivity -  $NE\Delta P - 0.1\%$   
 $NE\Delta T - 0.1\%$

## MISSION

Title: High Resolution Camera System Development

## OBJECTIVES

1. To provide the Shuttle with a quick response, high resolution photographic camera for coverage of transient or short-lived events and for support of applications development missions.
2. Camera to be operated from crew compartment of Orbiter to allow for selected high resolution coverage.

## JUSTIFICATION

1. The need for a quick response, high resolution camera for sizing damaged areas and required remedial action for unexpected transient or short-lived events, such as:
  - Disasters, fires, floods, and earthquakes
  - Red tide blooms
  - Oil slicks and spills, etc.
2. The need for high resolution coverage when scheduling does not allow for it as a prime payload, for investigations, such as:
  - Urban change analysis
  - Map revision
  - Ground truth for major operational programs (e. g. , crop inventories)
3. Shuttle use is justified because it can satisfy the need for short-notice camera operations and film recovery.
4. A high resolution camera is necessary for at least 4 of the 8 Applications Development Missions proposed for the earth resources areas.

## DESCRIPTION

An operational high resolution camera in the crew compartment is proposed. This camera should be pointable and available for use at any time. In addition, a high resolution camera is needed to support the applications development missions. There are several candidates.



1. S190B earth terrain camera
2. JPL 4-band camera, under development
3. S190A 6 band camera
4. Large Format Mapping Camera

#### INTRA-EARTH RESOURCES SYNERGISM

The Earth Resources Mission Sensor Requirements are shown in Figure 3-4. These sensor requirements lead to a number of statements concerning intra-earth resources synergism.

The most obvious of these is that sensor development mission are coincident with applications development missions employing those sensors. For example, the SAR may be used in the mineral exploration program during its development.

The next type of synergism is due to commonality of equipment. For example the sensors required for the World Crop Survey Program are a subset of the sensors required for the vegetation stress and analysis program. In addition, the areas of coverage are coincident. In another example, the urban/regional land use and timber inventories require the same sensors, however they require different areas of coverage and frequency bands.

A third type of synergism is that in which data from one application development program, is useful in another. For example, the World Crop Survey Program may initially locate areas of interest for the Vegetation Stress and Analysis program. Similarly the first stage sampling of the Timber Inventory Program may be useful in the Regional Land Use Inventory Program.

In this regard it may be stated that any earth resources applications development program will supply at least partial data for any other program if the coverages and frequency allocations on the scanners can be scheduled properly.

	S.A.R.	S.I.M.S.	M.M.S.	HI-RES CAM.
1. SAR	X			
2. SIMS		X		
3. MMS			X	
4. HI-RES. CAM.				X
5. WORLD CROP SURVEY	X	X	X	X
6. VEG. STRESS	X	X	X	X
7. URBAN INV.			X	X
8. TIMBER INV.	X		X	X
9. RANGE INV.	X	X	X	
10. MIN. EXPL.	X		X	X
11. MARINE RES.	X	X	X	
12. WATER INV.	X	X	X	

Table 3-10 shows additional Earth Resources Missions.

Figure 3-4. Earth Resources Mission Sensor Requirements

Table 3-10. Additional Earth Resources Missions

Mission	Shuttle Role	Description	Typical Users	Shuttle Justification	Mission Importance	Mission Maturity	Recommended Sensors	Reason for Alternate Status
Marine Navigation Hazard Monitoring	Application Development	Provide Highly Accurate Information on Extent and Locations of Navigation Hazards such as Sand Bars, Shoals, Land Mass, and Reefs.	NOAA, U.S. Coast Guard, Foreign Oceanographic Offices.	Ability to Provide High Resolution on a Global Basis from Tailored Orbits; Ability to Tailor Local Lighting for Water Penetration.	Moderate; Potential Cost and Quality Improvement in Producing Existing Products.	Low; Significant Questions Exist Concerning the Ability to Routinely Sense Hazard Dynamics.	M. M. S. HI. RES. CAM.	Mission Maturity.
Landform and Cover Mapping	Application Development	Periodically Provide Data from Which a Variety of Physical Characteristics Themes may be Made and Their Temporal Changes Detected Over the U.S.	U.S. Geological Survey, Bureau of Land Management, Soil Conservation Service, State Natural Resources Dept.	Ability to Provide Synoptic Coverage at High Resolution Over Regional Areas; Ability to Tailor Lighting, Spectral Response, and Resolution.	Moderate; Economic Benefits not Determined.	Moderate; Aircraft Experience and Landsat Investigations Encouraging.	M. M. S. HI. RES. CAM. S. A. R.	Mission Importance Note: This is closest to an "A" Mission.
Impounded Water Supply Inventory	Application Development	Provide Data on at Least a Regional Basis to Allow the Inventory of Impounded Surface Water Supplies.	Corps of Engineers, Bureau of Reclamation, Soil Conservation Service, State Water Resources Agencies.	Ability to Simultaneously Cover Regions with Synoptic and High Resolution Sensing.	Moderate; Potential Quality and Cost Improvements of an Existing Operation.	Low; Little Experience on a Regional Basis; Some Local Efforts Successful.	HI. RES. CAM. M. M. S. S. A. R.	Mission Maturity. Bathymetric Measurements Necessary.
Monitoring of Pollution from Mineral Extraction	Application Development	Periodically Monitor and Inventory the Areal Extent of Strip Mining Operations, and the Quality, Progress, and Legal Compliance of Their Restoration.	Environmental Protection Agency, U.S. Geological Survey, Bureau of Land Management, Bureau of Mines, Mining Companies.	Efficient Coverage of Statewide Areas.	Moderate to High; Statutory Requirements Firming.	Moderate to High; Several Landsat and Aircraft Projects have Achieved Results.	HI. RES. CAM. M. M. S.	Low Economic Benefits.
Assessment of Farming Practices	Application Development	Provide the Remotely-Sensed Inputs to an Integrated Farming Practices Correlation Model, Including Data Cultivation Cycles, Methods, and Crop Yield.	Soil Conservation Service, Economic Research Service, Agricultural Research Service, State Agricultural Department.	Efficient Multi-Resolution Coverage of Widely-Dispersed Sites.	Moderate to Low; Remote Sensing not a Major Part of Total Requirements, but Overall Economic Benefits High.	Low; Landsat Investigations not Significantly Addressing Area.	HI. RES. CAM. M. M. S. S. A. R. S. I. M. S.	Mission Maturity.
Forest Fire Damage/Regrowth Assessment	Application Development	Periodically Monitor Areas which have been Devastated by Forest Fire to Inventory Their Extent, Quality of Restoration, and Regional Environmental Effects.	U.S. Forest Service, National Park Service, Bureau of Land Management, State Forestry Departments, Private Lumber Companies.	Efficient Multi-Resolution Inventory of Widely Dispersed Sites; Ability to Orthographically Record Regional Context Simultaneously at High Resolution.	Moderate to Low; Potential Quality Increase for Existing Function.	Moderate; Several Aircraft and Landsat Projects Used for Specific Fire-Damaged Areas.	HI. RES. CAM. M. M. S.	Mission Importance.

### 3.4 EARTH AND OCEAN DYNAMICS

The major applications objectives of the EVAL Earth and Ocean Dynamics missions are taken to be those declared in the 1972 Earth and Ocean Physics Applications Program document (1), namely:

1. Development and validation of methods leading to Earthquake-Hazard Assessment and Alleviation Models to predict probable time, location, and intensity of earthquakes.
2. Development and validation of means for predicting the general ocean circulation, surface currents, and their transport of mass, heat, and nutrients.
3. Development and validation of methods for synoptic monitoring and predicting of transient surface phenomena, including the magnitudes and geographical distributions of sea state, storm surges, swell, surface winds, etc., with emphasis on identifying existing and potential hazards.
4. Refinement of the global geoid, extension of geodetic control to inaccessible areas including the ocean floors, and improvement of knowledge of the geomagnetic field for mapping and geophysical applications, to satisfy stated user requirements.

Further motivation for the selection of EVAL missions has come from the "Outlook for Space" study; from the EVAL working group interim meeting; from the papers contained in the "Sea Sat-A Scientific Contributions" (2) and from the "Marine and Maritime Uses" supporting paper of the PASS Study (3). Some "Strawmen" missions that have been considered are:

1. Crustal Motions Monitoring Experiment
2. Geomagnetic Field Measurements
3. High Resolution Sea Surface Temperature
4. Ocean Waves Experiments
5. Ocean Current Experiments
6. Low Inclination Ocean Geoid Measurement
7. Land Topography Mapping
8. Sea Ice Survey

9. Storm Hazards Assessment
10. Gravity Field Experiments
11. Oceanographic Lidar

Descriptions of the first five enumerated missions are submitted below and descriptions of the remaining six follow in tabular form as Table 3-11. The documented "strawman" or "A" level missions were selected for some of the following reasons:

1. The development of a spaceborne system for monitoring crustal motions will benefit land management and Earthquake-Hazard Assessment Programs. Shuttle is an ideal test bed for the system, and the system development schedule is compatible with an early EVAL schedule.
2. Knowledge of the geomagnetic field and its variations is essential to an understanding of the earth's interior and dynamics, and the possibility of field collapse is of general concern to human life. Shuttle, while presenting problems with an unclean magnetic environment, is still a useful platform because of its low orbit. The magnetometers required will be available after the launch of Magsat in 1979.
3. "All weather" high resolution sea surface temperature directly benefits fisheries operations as well as oceanographic science. Shuttle is a convenient platform for large microwave radiometers.
4. The ocean waves experiments are intended to lead to an improved wind and wave monitoring system which will benefit coastal zone management and shore safety, as well as ship routing and design. While some of the proposed sensors are presently conceptual and not likely candidates for early EVAL flight, others will be available for early EVAL flights.
5. Knowledge of ocean currents is important to fishing, shipping, and oceanographic science. Shuttle is a convenient platform for multiple sensors to develop ocean current signatures.

Table 2-11. Additional Earth and Ocean Dynamics Missions

Mission	Description	Shuttle Role	Typical Users	Mission Importance	Mission Maturity	Sensors
Low Inclination Ocean Geoid Measurement	Mapping Of Ocean Geoid In Low Inclination Orbit Will Strengthen Geoid Developed By High Inclination GEOS-3 And SEASAT-A Altimeters	Operational-Mission Complete In 1-2 Sorties.	NASA, Smithsonian AST., OBS., DOD.	TBD	High; GEOS-C Unit Available	Pulse Compression Radar Altimeter
Land Topography Mapping	Mapping Of Land Topography Features To 2 Meters Over A 2.5 KM Swath; Reflectivity Measurements	Platform For Large Antenna Structures, High-Powered Laser. Instrument Technology Test Bed.	FAA, USDI, Geodetic Survey, USGS	High-Air Traffic Safety, Land Resources	Low to Moderate. Holographic Radar Is Major Development. Shuttle Lidar Under Study (ESA).	Beam-Limiter Radar Altimeter, Shuttle Holographic Radar, Shuttle Lidar, Multispectral Scanner, (e.g. Thematic Mapper)
Sea Ice Survey	Periodic Surveys (Monthly-Seasonal) Of Polar Ice Fields And Floating Ice	Convenient Platform For Several Large-Sensors. Sortie Mode Consonant With Periodic Surveys	NOAA, NAVOCEANO, International Ice Patrol, US Coast Guard.	High-Effects Climate, Ocean Dynamics, Shipping	Low. Requires Polar Orbit (Post 1983)	Shuttle SAR, SIMS Or SSMR, Shuttle Lidar, Radar Altimeter.
Storm Hazards Assessment	Measure Strength Of Tropical Storms-Surface Winds, Liquid Water And Water Vapor, Surface Temperatures, Wave Fields To Assess Landfall And Storm Surge.	Launch In Response To Storm And Tailor Orbit. Large Payload Capability	U.S. Weather Bureau, Nat. Hurricane Center	High-Storm Research And protection Of Life And Property	TBD. Capability For Timely Launch Uncertain	Shuttle SAR, SIMS Or SSMR, Microwave Radiometer, Radar Altimeter, Visible And IR Scanner.
Gravity Field Experiments	Measure Gravity Variations From Low Orbit; Test Response Of Gravity Gradiometers In Zero-G; Perform Satellite-Satellite Tracking.	Technology Development Platform; Launcher For Free Flyers (GRAVSATS); Operational If Tether Carried for 3-4 Sorties In Polar Orbit.	National Geodetic Survey, Defense Mapping Agency, USGS	Moderate-To-High-Improved Global Geopotential Goal Of NODAP.	Moderate. Gradiometer GRAVSAT Needs To Be Built	Rotating Gravity Gradiometer, Doppler Tracker And X Ponder, Laser Tracker And Retro-Reflector Satellite.
Oceanographic Lidar	Measure Turbidity, Temperature, Salinity L. Depth; Perform Shallow Water Bathymetry. Fluorescence Signatures.	Technology Development Platform. Capability For Large High-Power Laser	NOAA, Nat. Marine Fisheries Service	High - Heat Content Of Upper Mixed Layer Important. Supports Fisheries And Ocean Color Research	Moderate. Requires 1 Joule Blue-Green Lasers And 1 m <sup>2</sup> Collectors (1978-1980). (Shuttle Lidar Development)	Shuttle Lidar And 3 Channel Processor, Multispectral Scanner (e.g. MOCS). Thermal Mapper.

## MISSION

Title: High Resolution Sea Surface Temperature and Salinity

## OBJECTIVE:

1. Demonstrate high spatial resolution (5-10 km) microwave radiometric mapping of sea surface temperature for application to circulation studies and modeling, fog prediction, routine upper ocean analysis and forecasting, and fisheries operations.
2. Explore the feasibility of L-band radiometry for global and coastal salinity measurements.

## JUSTIFICATION:

The distribution of sea surface temperature (SST) is an important parameter in the marine and atmospheric sciences. Synoptic views of sea surface temperature as obtained from satellite infrared measurements have proven to be valuable in revealing circulation patterns in the upper ocean—patterns of currents, eddies, and oceanic fronts - and of providing information on the basic time and space scales of transient oceanic motions that can not be obtained from surface-based surveys. The synoptic views obtained from space have already been used to guide and support detailed oceanographic surveys of particular regions.

Large-scale anomalies in sea surface temperature of only 1-2 degrees centigrade have been related to changes in the atmospheric circulation patterns that can effect continental weather changes over seasons or years. The genesis and movements of hurricanes are critically related to water temperature: hurricanes appear to develop only when the SST is above 27° centigrade.

The Advanced Very High Resolution Radiometer (AVHRR) planned for TIROS-N in 1978 and for a succession of NOAA polar orbiter satellites will provide infrared SST determinations at 1 km resolution; averaging of the data over 10 km squares should yield absolute accuracies of  $\pm 1^{\circ}\text{C}$  and relative accuracies of  $\pm .5^{\circ}\text{V}$  (Sherman and Rao, 1974). To obtain this accuracy, clear skies are required, and corrections must be made for residual water vapor effects in the 10-12 $\mu\text{m}$  atmospheric window (this is done using two frequencies within the window band). Because of the slowness of most transient ocean current changes, compared to atmospheric variability, thermal images of current systems can be built up by mosaicing a succession of IR clear sky views. However, in regions of persistent cloudiness or fog this will not be possible. This may be of practical importance in many fisheries where the cloudiness and fog is high, such as the Grand Banks. A more nearly all-weather microwave radiometric system would appear to offer advantages in providing a more timely, uninterrupted flow of SST data.

Despite the above quoted accuracies of infrared SST determination, there still are questions regarding the accuracy. Ruskin and Jeck (1974) mention an instance where satellite IR data underestimated SST by 16°C. One may also raise the question of a possible bias in IR SST obtained in clear sky regions only. This experiment with a multifrequency microwave radiometer should allow further comparisons of IR, microwave and bulk SST measurements for comparable resolution scales, and further, the high resolution data will support a better interpretation of the lower resolution microwave radiometric data from an operational satellite like Nimbus-G, for example, by being able to resolve rain cells.

A multifrequency scanning microwave radiometer such as the Shuttle Imaging Microwave System (SIMS) is potentially capable of a 1°-2°C accuracy. Greater accuracy may be obtained under ideal conditions or from areal averaging. The microwave frequencies most sensitive to the surface temperature lie on the C-band region around 5-6 GHz. A multispectral approach is required to correct for atmospheric and surface roughness effects.

An optimal configuration for minimizing surface roughness effects is for vertical polarization and an approximately 50 degree incidence angle. The Nimbus-G SMMR is so configured, but the SIMS is not (the SIMS has cross-track scan through nadir.) From an experimental point of view, one would like flexibility in choice of nadir angle for optimizing SST determination.

While microwave SST measurements are potentially capable of satisfying most user requirements, the situation with salinity measurements is very problematical. Useful oceanic salinity measurements must be accurate to at least 0.05 ppt. The sensitivity of L-band brightness temperature to salinity is about 0.5°C/ppt. Thus a radiometric temperature accuracy of 0.025°C is required. Even if the radiometer were capable of this accuracy, the effects of surface roughness and atmospheric effects would mask the salinity signal. Thus, in this mission, the measurement of salinity is only regarded as exploratory. It is only mentioned at all since the SIMS (for example) will have an L-band channel. Unfortunately in coastal waters where the salinity gradients can be large, the spatial resolution of the L-band radiometer will generally be too poor (20-40 km) to be useful.

Besides measuring SST the multifrequency microwave radiometer will obtain roughness information relatable to the wind stress (or speed) and the white cap index. (In fact, estimating wind speed to ± 2m/sec is essential to estimating the SST to 1°-2°C). Thus, the experiment will support air/sea intersection studies on the mesoscale.

Shuttle is a convenient platform for flying large instruments like the SIMS. The sortie mode allows for a more rational applications development before commitment to an operational phase.

Potential users interested in this mission include NOAA, the National Marine Fisheries Service, the Naval Oceanographic Office, Fleet Numerical Weather Central, the fishing industry, and university oceanographic institutes.

#### DESCRIPTION:

Experience with the Nimbus-G SMMR will aid in the analysis of the data obtained from this experiment, specifically in determining the initial inversion algorithms. The mission will consist of proving the measurement techniques in some well instrumented areas (e.g. where surface surveys are in progress). Concentrated measurements will be made in the Grand Banks area, in upwelling regions (off the Spanish Sahara or Peru, for example) and in the intertropical convergence zone (to attempt to detect the counter-current under the cloud cover).

AVHRR data from an operational NOAA satellite is required for this mission. Some underflights with IR and microwave radiometers would be desirable, in clear sky, and under cloud cover.

The only instrument required for this mission is a scanning multifrequency microwave radiometer. The Shuttle Imaging Microwave System (SIMS) is under development at the Jet Propulsion Laboratory and is being scheduled for FY 1980 Shuttle availability. The Nimbus-G SMMR engineering model is being developed for 1979 availability at GSFC and is intended to be a part of a larger system of radiometers (Shuttle Scanning Microwave Radiometers - SSMR) that would be similar to SIMS.\* The mission would be complemented, however, by including a scanner like the CZCS, and a microwave scatterometer like the S-193.

#### References:

<sup>1</sup>Sherman, J. W. III and P. K. Rao, Microwave Measurement of Sea Surface Temperature, in Seasat Scientific Contributions, NASA, 1974.

Ruskin, R. E. and R. K. Jeck, Jr., Requirements for Sea Surface Temperature and Surface Wind Measurements from Seasat A, on Seasat Scientific Contributions, NASA, 1974.

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\*The L-band radiometer component of the SSMR uses the 3m Adaptive Multibeam Phased Array (AMPA) which is a Communications/Navigation experiment.



## MISSION

Title: Crustal Motions Monitoring Experiment

## OBJECTIVE:

The objective of this experiment is the testing and demonstration of a precision spaceborne laser ranging system for measuring small relative crustal motions (on the order of centimeters/yr). The experiment will involve ranging to a number of ground emplaced retroreflectors placed on a grid arrangement. The goal is the recovery of intersite distances (horizontal and vertical) to centimeter accuracy. It is expected that this may be accomplished on a seven day Shuttle Sortie mission. Repeated missions over a several year period might allow a prototype operational demonstration.

## JUSTIFICATION:

A spaceborne crustal motions monitoring system such as proposed operationally for the Geopause and Clogeos satellite systems would have several important applications, such as:

1. Measurement of subsidence for land management
2. Measurement of regional strain fields and local dilatancy for earthquake hazard prediction.
3. Measurement of plate tectonic motions
4. Measurement of glacial flow

Land subsidence on the order of 5-10 cm per year is occurring along the Gulf Coast of Texas and portions of the Florida Coast. The threat to property from inundation is, of course, enormous. Accurate monitoring of known or suspected subsidence areas would assist in land management and real estate decisions.

Major faults such as the San Andreas fault in California occur at the boundaries of the major tectonic plates. These plates are in relative motion on the order of several cm/yr. If a fault becomes locked or resists slippage, stress and strain will build up in the region surrounding the fault until a critical stress is reached and fracture occurs. The accumulated strain energy is then released, generating the earthquake. Measurements of regional (e.g. distances up to several hundred km from the fault line) strain fields and plate motions when combined with historical data and a knowledge of the physical properties of the rock in the fault region should permit a first-order assessment of the earthquake threat.

A number of physical changes associated with the phenomenon of rock dilatancy may be observed prior to an earthquake in the region around the earthquake focus. One manifestation of dilatancy is a crustal swelling with vertical displacements of several centimeters. The size of the dilatant region (typically several tens of kilometers) is supposed to be related to the magnitude and the probable time of occurrence of an earthquake (the precursor time intervals may range from several months to a few years).

This experiment will represent an important step in the EODAP program. It directly contributes to the Earthquake Prediction and Crustal Dynamics objectives of the "Outlook for Space". A regional strain field and dilatancy monitoring system for a single fault system like the San Andreas would require several hundred stations distributed over the thousand km length of the fault to be surveyed every 3 months or so. Surface techniques are clearly impractical. Ground-based laser tracking of a retroreflector satellite is also impractical since the deployment of a large number of expensive (about \$1.5 million) laser trackers would be required. Hence, the idea of a spaceborne laser with passive retroreflectors on the ground is attractive. Shuttle offers a unique test bed for evaluating the technology and measurement sensitivity of this rather complex system. Users of data provided by an operational system would include the National Geodetic Survey, the U.S. Geological Survey, and state and local governments.

#### DESCRIPTION

A detailed description of this Shuttle-based laser ranging experiment has been given by Fitzmaurice *et al.* (1975). An initial experiment might involve the deployment of about a dozen retroreflectors on a 25 km grid over a 100 km area. Geodimeter surveys of the sites will provide a "ground truth" at about a 2 cm accuracy level.

Data taking will start when the line of sight to the ground targets exceeds a 20° elevation angle. Range measurements with 5-10 cm single shot precision to each target will be taken at a rate of 5 per second interval. Each target will be acquired and ranged on sequentially until the end of the pass when the elevation angle reaches the 20° cutoff. (Another possible measurement approach is to range simultaneously on two (or possibly more) targets. This could be accomplished using a wider beam, or possibly split beams. With simultaneous ranging, first order measurement biases can be eliminated as discussed by Vonbun *et al.* (1975). At this point, the final measurement approach remains to be determined.) Repeated passes are required to recover intersite distances to the cm level. On subsequent missions displacement of a cluster of targets might be used to simulate dilatancy and further test the sensitivity of the system.

The sensor system consisting of a Nd:YAG laser and receiver, and pointing optical flats or Coude elements will require attitude stability to 2 mr, which can be provided by the Small Instrument Pointing System (SIPS). Pointing and control systems will be

directed by a small computer such as a PDP-11 which will be fed with Shuttle ephemeris data. A Payload Specialist will be expected to monitor the system, specifically to confirm that targets are being acquired and tracked. An orbit inclination equal to the latitude of the target area selected will be required to maximize the number of passes.

Pressure, temperature, and humidity gauges at several of the sites will be needed for making refractive index corrections.

A brassboard version of a 10 cm precision Nd:YAG laser ranging system using space qualifiable components is currently being developed and tested at GSFC under OAST funding. Further development is required to produce an engineering model of the spaceborne system that would have full acquisition tracking, and beam steering capability. Funding for this phase is being sought for under the AAFE Program. Construction and testing of the flight unit could meet a 1981 Spacelab flight schedule.

#### References

Fitzmaurice, M. W., P. O. Minott, and W. D. Kahn, "Development and Testing of a Spaceborne Laser Ranging System Engineering Model." GSFC Rpt. X-723-75-307, Nov. 1975.

Vonbun, F. O., W. D. Kahn, P. D. Argentiore, D. W. Koch, and K. J. Eng., "Spaceborne Earth Applications Ranging System," GSFC Rpt. X-920-75-299, Dec. 1975.

## MISSION

Title: Geomagnetic Field Measurements

## OBJECTIVES

Global geomagnetic surveys will be conducted through the Shuttle era using Shuttle as a measurement platform and as a launcher for free-flyers (Magsats). Precision scalar and vector magnetic field measurements obtained from low-altitude orbits will be used for the detection of local anomalies, and generating accurate, up-to-date global models of the earth's magnetic field and its secular variations.

## JUSTIFICATION

Improved knowledge of the earth's magnetic field is a stated goal of the EODAP program and is a key earth science objective in the "Outlook for Space Study". To quote from the "Outlook for Space":

"Study of the earth's magnetic field is important because understanding the composition and dynamics of the Earth's interior is fundamental to understanding the planet we live on, and because fluctuations in the geomagnetic field may affect the biological environment on the earth's surface. Magnetometer surveys of the Earth, to nanotesla accuracy, are a necessary ingredient to achieve this understanding.

The geomagnetic field is one of the few observables containing information about the interior of the Earth. It is thought to be caused by dynamic action in the liquid outer core of the Earth, and the field contains components from the source in the core and from magnetized material in the upper lithosphere. Variation of the main field may reflect changes not only in the source process, but also modulation of changes in the conducting mantle. Ambient variations caused by magnetospheric source also cause shallower currents which are modified by the lithosphere. The total spectrum of the internal field and the Earth's response to transient variations may give clues to global tectonic structure. The geomagnetic field shields the Earth's biosphere from potentially harmful solar radiations, so fluctuations in the field strength, or conceivably field reversals, are of immediate practical importance".

Satellite global magnetic field data obtained from the Pogo series has proved to be valuable in describing the secular variations of low-order field components. Because the secular rate is really not constant, periodic surveys on a 4-7 year time scale are required to keep the field up-to-date, and satellites are the only way to obtain global information at a reasonable cost. Global models of the field and its secular variations are useful for the preparation of magnetic charts for navigation

and other purposes and in background removal in aeromagnetic and shipborne surveys used in geophysical prospecting and scientific studies of the continental and oceanic crust, as well as being invaluable in studies of the inner earth.

Satellite magnetic field data on a 100-300 km resolution scale such as might be obtained from very low orbits, will enable the detection of regional anomalies, which might be used to identify valuable mineral deposits, or geothermal energy sources. Combined with gravity and seismic data, accurate magnetic data on this scale will provide a better basic understanding of crustal dynamics and plate tectonic processes.

Users involved in this experiment include NOAA, the U.S. Geological Survey, DoD, Energy and Mineral Companies, and University Observatories.

### DESCRIPTION

Langel (unpublished manuscript, 1975) has discussed a possible implementation plan for geomagnetic field measurements in the Shuttle era. The plan calls for four automated spacecraft in low (300 km) circular polar orbits separated by 8 hours local time, and a fourth in a higher (600-1000 km) polar orbit. This configuration will allow for the separation of magnetospheric effects depending on local time. Repeat measurements every five years will be required to maintain an accurate determination of the secular change. In order to achieve the best possible resolution and sensitivity in the measurement of lithospheric anomalies, the automated spacecraft would be complemented by lower altitude measurements from the Shuttle platform itself. Two such missions, of seven days duration, are planned for each year for eight years. Particular emphasis will be placed on those geographic areas shown to be of interest by measurements from the automated spacecraft.

To achieve the goal of  $\pm 5\gamma$  (nanoteslas) measurements of the vector magnetic field components, the magnetometer will have to be removed from the disturbing fields of the Shuttle, and this will probably require a boom of considerable length (several tens of meters). Further, vector field measurements will require high accuracy in magnetometer attitude determination. A  $\pm 5\gamma$  accuracy on the field components of a 50,000 $\gamma$  field will require sensor attitude determination to within 20 arc-seconds, and this probably cannot be accomplished with the attitude sensor on Shuttle separated from the magnetometer by the long boom. A dual package consisting of the magnetometer and an attitude determination system (ADS) separated by a relatively short rigid boom will ride on the end of the long boom. The separation of the ADS and magnetometer is necessary, because the ADS will be somewhat magnetic.

(Another possibility for Shuttle magnetic field measurements is currently being explored. A magnetometer could fly in a very low orbit (100 km) tethered to Shuttle. The "Skyhook" concept is attractive for magnetic field measurements, as well as for gravity field measurements with gravity gradiometers for the same reason, namely, that greater proximity to the sources in the upper mantle and lithosphere will mean greater sensitivity and spatial resolution.)

The orbit should have a minimum inclination of  $50^\circ$ , and an apogee/perigee of 250/200 pm with a maximum of 300/250. It would be desirable to have Shuttle position information to 30 m in altitude.

The  $\pm 1\gamma$  scalar alkali vapor magnetometer required for this experiment is already developed. Design of a  $\pm 5\gamma$  flux gate vector magnetometer has been completed at GSFC, and RFP's for the fabrication of the magnetometer are being issued. The schedule should have the magnetometer available for a 1979 Magsat launch. Star cameras for the ADS are readily available.

## MISSION

Title: Ocean Currents Experiment

## OBJECTIVES:

The objective is to develop a multi-sensor signature for detection and mapping of ocean currents, eddies, and internal waves, and to further understanding of the interactions of currents with waves. The ultimate objective is to measure magnitudes and directions of current flows. This experiment will be accomplished using joint signatures of ocean color, thermal contrasts, sea level topography and current and wave interaction effects.

## JUSTIFICATION:

Ocean currents contribute a significant fraction of the total transport of heat from the tropics to the poles, and are important to the global climatic balance. Recently, it has been recognized that a major fraction of the kinetic energy in the ocean is associated with quasi-geostrophic eddies on the scale of several hundred kilometers. These eddies play a major role in the general circulation, and knowledge of their distribution and time and space behavior is needed to parameterize the general ocean circulation models. The relative importance of different sources of internal wave generation are not entirely understood - surface sources may be from non-linear interactions of surface waves, or from wind stress. Better knowledge of currents will benefit ship routing and fisheries, as well as oceanographic science. Potential users include NOAA, the National Marine Fisheries Service, and the shipping industry.

## DESCRIPTION:

Presently the only methods of satellite remote sensing of oceanic currents are thermal IR imagery, and visible color and reflective changes. Satellite IR data has obtained synoptic pictures of several current systems and eddy structures. Landsat MSS imagery has been used to study currents, and has detected in several instances internal wave patterns. Airborne SAR imagery has shown strong reflectivity changes delineating Gulf Stream filament features. The reflectivity changes may be caused by direct interaction of surface waves with current gradients, or by changes in surface tension. In this experiment multispectral radar imagery will be combined with multi-spectral visible and IR imagery to detect current features. The X and L bands (and possibly a K-band) of the Shuttle SAR should enable a distinction to be made between direct wave-current effects (L band) and surface tension effects (X & K bands). Detection of currents through changes in color will require pointing away from the sun, while the detection of surface reflectance changes would be enhanced by solar reflection. A shared FOV between the SAR and visible and IR sensors is required. The CZCS (Coastal Zone Color Scanner) has a  $\pm 40^\circ$  cross-track scan and will include the SAR swath except for the largest SAR nadir angles. A 10 cm precision radar altimeter is potentially capable of measuring sea surface slopes relatable to surface

current speeds through the geostrophic balance. The successful measurement of sea surface slopes requires a knowledge of the geoid. It is assumed that in the post Seasat-A period, the geoid, say of the East Coast of the U.S., will be sufficiently well known that Shuttle-based sea-slope measurements will be able to be used for current measurements. The altimeter will also function to detect roughness changes and wave height changes at current boundaries.

This mission should first be concentrated on strong western boundary currents such as the Gulf Stream and Kuroshio, and in areas where internal wave patterns have already been observed. Growth of an instability in the Gulf Stream may be detected in a 7 day mission. Later observations might be made to attempt to detect mid-ocean eddy structures. Any observations of this kind should be made in conjunction with surface experiments such as MODE. The orbital altitude should be as high as possible consistent with SAR performance criteria, to maximize coverage.

The primary instrumentation for this experiment in the Shuttle multi-frequency SAR, the CZCS and the Radar Altimeter. Desirable additional instrumentation would include the Thematic Mapper, a microwave scatterometer such as the S-193, and a multi-frequency microwave radiometer.



## MISSION

Title: Ocean Waves Experiments

### OBJECTIVE:

A series of Ocean Waves Experiments will be conducted to further the development of wave measurement sensors technology and measurement techniques. The experiments will provide to a limited extent (a) verification data for the improvement of wave forecasting models and (b) coastal zone wave climatology data.

### JUSTIFICATION:

One of the objectives of the Seasat-A mission is the monitoring of sea state for the purpose of providing verification data for wave forecasting and for gathering data on global and coastal zone wave climatology. The sensors selected for the Seasat-A mission are a 10 cm pulse compression radar altimeter and an L-band synthetic aperture radar. During the period of Seasat payload definition, a variety of alternative sensors and measurement techniques were suggested as possible alternatives for obtaining sea state, particularly directional wave spectra. Space Shuttle offers an opportunity for testing out some of these experimental sensors at low risk and for performing comparisons between techniques; and with the advent of the Shuttle SAR -- with its frequency and polarization diversity and variable look angle -- further refinement of the SAR approach will be possible.

This mission is directed to the objective in the "Outlook for Space" study: "Provide a Global Marine Forecasting Capability for Support of Maritime Activities." As pointed out in that study, the world merchant fleet has been expanding and ships are being built at ever increasing tonnage. Improved knowledge of global wave statistics will be useful in the design of new supertankers (Very Large Crude Carriers), and will help fix more efficient standard routes. Optimum ship routing based on improved forecasting is estimated to result in benefits of \$30-\$50 million per year for U.S. trade alone. Wave data in the coastal zone in the form of seasonal climatologies and routine forecasts are needed for the design and situation of offshore structures and for conducting daily offshore operations. Coastal zone wave data such as obtained by the SAR will contribute to a better understanding of shoreline transformation, and will promote an improved shoreline management.

There are a multitude of users for the information obtained from this experiment, including the U.S. Navy Fleet Numerical Weather Central, NOAA, The Naval Oceanographic Office, U.S. Coast Guard, U.S. Army Corps of Engineers, the Maritime Administration, ERDA, shipping companies, the fishing industry, and oil and mineral companies.

### DESCRIPTION:

The instruments considered for these experiments are: the Shuttle SAR; a Pulse Compression Radar Altimeter (PCRA); a HF Bistatic Directional Wave Spectrometer;

a Wave Motion Sensor; and a Microwave Directional Wave Spectrometer (Surface Spectrum Radar). Some of these sensors may be flown independently or in concert. These sensors are described briefly below.

1. The Shuttle SAR will be exercised in a global sampling mode (occasional "snapshots" over various sea conditions) and more intensively in various coastal zones (e.g., 100 km strips). Wave imagery and derived spectra will be compared for various look angles, polarizations, and frequencies (X and L bands.)
2. It will be desirable to carry the PCRA on most flights since (a) at present it is the only space proven instrument and (b) it operates synergistically with the SAR and other instruments. The PCRA measures the wave height at satellite nadir. The GEOS-3 engineering model would be suitable for this experiment.
3. In the HF Bistatic Directional Wave Spectrometer experiment, a small receiver aboard Spacelab will measure the intensity and Doppler shifts of Bragg sea-scattered signals in the 3-50 MHz range from about 20 inexpensive transmitters placed at shore stations or on buoys and ships. The measurement product is the wave-height directional spectrum at discrete spectral intervals. The experiment is relatively mature and a candidate for early EVAL flight. Aircraft testing of the system has been conducted by Batelle-Columbus Laboratories and NASA/Wallops Flight Center.
4. The Wave Motion Sensor is an interrupted CW microwave system designed to measure the surface Doppler spectrum from a moving platform. The system can be implemented for fixed nadir viewing or wide swath modes. The output product is the rms vertical velocity of the waves. The instrument operates synergistically with the altimeter: from the altimeter wave height data and the vertical velocity data the significant wave period can be derived, and departures from equilibrium seas may be detected. The instrument is presently conceptual (Applied Physics Laboratory study for NASA/Wallops Flight Center), and development through an AAFE stage is required. The experiment is a candidate for later EVAL flights.
5. The Microwave Directional Wave Spectrometer uses a conically scanning antenna to measure the two-dimensional reflectivity spectrum of the surface (or directional wave spectrum). The instrument, which can theoretically be implemented in a short pulse of dual-frequency interferometric mode, is presently conceptual as a space instrument. Aircraft testing by GSFC is lending to proof of concept. The instrument is a candidate for later EVAL flights.

These experiments should first be conducted in Northern Hemisphere winter when some storm seas can be counted upon and where the greatest surface truth is available. Additional instrumentation for this mission might include a telescope/camera for measurements of waves in the sun's glint, and a microwave scatterometer for wind vector determination. A 57° inclination is desirable.

POTENTIAL LASER APPLICATIONS TO EARTH AND OCEAN DYNAMICS. Space Shuttle offers a unique opportunity for the development, testing, and demonstration of spaceborne laser instrumentation for a variety of Earth and Ocean Dynamics applications. Some possible Shuttle-era laser experiments and applications that might be accomplished within the scope of EVAL are discussed here.

Crustal Motions Monitoring. This is identified as a prime EVAL E&OD mission and is discussed in some detail in the "Strawman mission" section. The experiment utilizes a Spaceborne Laser Ranging System (SLRS) configured about an essentially "off-the-shelf" Nd:YAG Q-switched laser (5 ns, 0.05 joule pulses at 5 pps). With a 15 cm receiver aperture (0.6 mr FOV) and retro-reflector cross sections of  $10^7 \text{m}^2$ , the system will be capable of 5-10 cm ranging to ground targets at ranges of 400-1000 km.

Satellite-to-Satellite Tracking. Radio doppler satellite-to-satellite tracking (SST) has since the start of the EODAP been considered as a method for obtaining intermediate-scale global geopotential information. A radio Doppler experiment was carried out during the Apollo-Soyuz Test Project, and is presently being carried out between the ATS-6 and the GEOS-3. Conceivably, the Crustal Motions SLRS could be used in performing some Shuttle-based low-low and high-low SST experiments. (For example, between Shuttle and Lasers). One may not want to involve the Crustal Motions SLRS in an SST experiment because of operational complexities in switching from one experiment to the other. A function of a Shuttle laser SST experiment might be to check out and calibrate a dual-doppler satellite pair in orbit.

Laser Altimetry and Profiling. It is difficult to see Lidar altimetry displacing the already well established microwave radar altimetry in operational-type measurements of sea surface topography, the ocean geoid, and sea state. The microwave techniques have a long lead in technological development, and have the advantage of being nearly immune to weather. However, some interesting experiments could be performed with a laser altimeter and radar altimeter in the area of calibration and of bias discrimination determined in orbit. Plotkin\* has described a spaceborne ocean surface laser altimeter for operation in a 1000 km orbit. The laser is 3 ns, 0.25 joule frequency doubled Nd:YAG laser pulsing at 3-400 pps. The receiver collector diameter is 0.3 m and the FOV is 0.15 mr. At lower Shuttle orbits, these figures could probably be

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\*Plotkin, H.H. Design Considerations for a Space-Borne Ocean Surface Laser Altimeter in NOAA Sea Surface Topography from Space, Vol. 1, NASA CR 130293, 1972

relaxed. (Conceivably, the Crustal Motions SLRS could perform the altimetry function - at least for calm seas). The use of the European Shuttle Lidar (Large Space Telescope) should be studied for application to sea-surface altimetry. Particular attention must be paid to nadir alignment with the LST.

Initial experiments with the laser altimeter would be similar to the pioneering experiments with the S-193 altimeter. Pulse shape characteristics and scattering cross sections would be investigated for various sea states. With a  $10^{-4}$  radian laser beam-width and a 400 km orbit, continuous terrain profiling at 40 m resolution will be possible provided a sufficiently high pulse repetition rate. This would be very useful in polar ice studies. Perhaps the greatest application of this system would be in the Earth Resources Discipline, where crop and forest heights could be determined.

Oceanographic Lidar. For several years, airborne lasers have been used for surface wave profiling to obtain wave heights and spectra. Recently, airborne lasers have been used for coastal bathymetry (depths less than 6 m) and for fluorosensing of oils and chlorophylls. Oils have a rather high interaction cross section, and the peak fluorescence wavelength is related to the API number of the oil. Recent laboratory studies have confirmed the feasibility of measuring water temperature in depth through Roman backscatter to  $1^{\circ}\text{C}$ . Circular polarization discrimination must be used to cancel the effects of selective color absorption in natural waters. Brillouin scattering can also yield temperature data, i.e., sound velocity data. In summation, laser probing has the potential for:

- Coastal bathymetry
- Subsurface temperature profiling
- Turbidity and transparency measurement
- Detection and measurement of oils and chlorophylls.

Because of the exponential attenuation of the laser beam with depth, high powered lasers are required even at aircraft altitudes. Wavelengths of maximum penetration depend on water type and vary from 450 nm in clear water to 510 nm in turbid coastal water. If the depth of the thermocline can be determined on a global scale (perhaps through a combination of Roman scattering and turbidity profiles,) this would have a great benefit to ocean circulation modeling, long-range weather prediction and climatology. As stated in the National Academy of Sciences report "The Ocean's Role in Climate Prediction": "The most pressing problem is the monitoring of subsurface temperature, the key parameter in the scientific understanding of the changing ocean". Transparency, mixed layer depth, and chlorophyll concentrations are all key parameters in fisheries models. Combined laser and passive multispectral imaging should lead to improved interpretation of remote ocean color signatures.

It is expected that in the 1980-1982 time period blue-green lasers (e.g., Copper Vapor, Flashlamp Pumped Dye Lasers, and Nd:YAG lasers) will be capable of delivering 0.1-2 joule pulses with average powers of 40-1000 W. With the advent of the Large Space Telescope, some Shuttle Oceanographic Lidar experiments appear feasible, at least for the later 1980's. Some preliminary calculations by Wallops Flight Center personnel indicate that 30-100 W blue-green lasers transmitting 10-20 ns (3 ns for bathymetry) when used with the LST could perform from space. Different signal processing would be required for each Lidar function; for example, a fluorosensor would require a spectrometer. Because of the limited lifetimes of high-powered lasers, particular care must be taken in experimental design.

INTRA-DISCIPLINE SYNERGISM AND COMMONALITY. There is generally some degree of synergism between any of the ocean missions associated with this discipline. For example, data pertinent to either the Ocean Waves experiment or the Storm Hazard Assessment will be mutually beneficial to the other. Also, the Sea Surface Temperature experiment and the Ocean Currents Experiment will lead to additional data and enhanced mission value if flown together. Another example of synergism is the utilization of the altimeter flown on any of the ocean missions to provide precise Shuttle altitude determination which will be useful in reducing the magnetometer data obtained for the Geomagnetic Field mission.

Commonality of sensor requirements is apparent for most of the Earth and Ocean Dynamics mission. Instruments such as a Thematic Mapper or Large Format Camera are either required or desired for essentially all missions. Color scanners and radars such as SIMS or SAR are also sensors which are frequently used. Table 3-12 provides a compilation of sensor commonality for the Earth and Ocean Dynamics missions.

Table 3-12. Sensor Commonality

<div>Missions</div> <div>Sensors</div>	Spaceborne Laser Ranging System	Magnetometers	Pulse Compression Radar Altimeter	Microwave Scatterometer S-193	Multifrequency SAR	SIMS/SSMR	Wave Motion Sensor	Wave Directional Spec.	HF Bistatic Radar	CZCS	S-190B	Shuttle Holographic Radar	Shuttle Lidar	Beam-Limited Radar Altimeter	Rotating Gravity Gradiometer	MOCS	Large Format Camera	Thematic Mapper
Crustal Motions Monitoring Experiment	P																S	S
Geomagnetic Field Measurement	P																	
Ocean Waves Experiments		P	P	P	S	P	P	P									S	S
High Resolution Sea Surface Temperature				S		P				S							S	S
Ocean Currents Experiments			P	P	P	S				P							S	S
Low Inclination Geoid Measurement			P															
Land Topography Mapping											S	P	P	P				
Sea Ice Survey			S		P	P												
Storm Hazard Assessment			P	P	P	P												
Gravity Field Experiments	P														P			
Oceanographic Lidar													P			S		

P = Prime

S = Secondary

### 3.5 COMMUNICATIONS/NAVIGATION

The potential benefits to be derived from Shuttle/Spacelab flights for NASA's communications and navigations programs has been studied by the EVAL COMM-NAV Working Group. This group was made up of representatives from GSFC, LeRC, ARC, JPL and NASA Headquarters. The group reviewed fifteen potential missions for the EVAL program. Of the total missions, eight were selected for Category A and will be outlined in more detail in this report. The candidate missions evaluated are shown in Table 3-13, Category B missions are summarized at the end of this section, as Table 3-14.

The eight Category A missions can be grouped into three mission types as follows:

<u>Sensor Development</u>	<u>Techniques Demonstration</u>	<u>Operational Application</u>
AMPA	AMPA	DCMB
DCMB	BWCM	EEE
EEE	DCE	
LDASE	DCMB	
MWE	EEE	
	LDASE	
	MWE	
	SCPL	

Sensor development covers development of microwave antennas, receivers and transmitters for the frequency range of 0.4 to 43 GHz. The AMPA is a phased array antenna system operating at L-band, or Ku-band, and will have multibeam capability. The DCMB operates at UHF and has multiple fixed beams to sense coded earth based transmitters, located at widely spaced monitoring stations. The EEE has receivers to monitor earth emitted RF signals from UHF through Ka-band; the LDASE is a 30 meter high gain deployable antenna for high efficiency, high directional control of space to earth transmission of RF energy. The MWE will have equipment to study the effects of the earth's atmosphere on RF transmission techniques in the 20/30 GHz region.

Those missions grouped in the Techniques Demonstration type are primarily for demonstration prior to design for a Free-Flyer satellite at low orbit, or for eventual use on a synchronous satellite. All of the missions recommended for Category A fall into this type of mission.

Two missions could be Operational Application missions. The DCMB could be used for monitoring remotely located environment data collecting stations, and for semi-annual monitoring, e.g., a Shuttle flight could supply migration data. Although the EEE could be classified as a Free-Flyer candidate, operational data on repetitive Shuttle flights will supply a data base for this mission.

Table 3-13. COMM-NAV Working Group Strawman Missions

Category A

- Adaptive Multibeam Phased Array Experiment (AMPA)
- Bandwidth Compression Modulation Experiment (BWCM)
- Data Collection With Multibeam (DCMB)
- Data Compression Experiments for Shuttle/Spacelab (DCE)
- Electromagnetic Environment Experiment (EEE)
- Large Deployable Antenna Shuttle Experiment (LDASE)
- Millimeter Wave Communications Experiment (MWE)
- Self Contained Position Location (SCPL)

Category B

- Antenna Range Experiment (ARE)
- Attitude and Position Interferometer Experiment
- Cooperative Surveillance Radar (CSR)
- Microwave Power Transfer
- Millimeter Wave Large Aperture Antenna (MWLA)
- NAVSTAR/GPS Experiment (GPS)
- Open Vacuum Tube Experiment



Table 3-14. Category B COMM-NAV Missions

Reference Number	Title	Shuttle Role	Mission Description	Typical User	Use of Shuttle	Mission Importance	Sensor Development
1	Millimeter Wave Large Aperture Antenna (MWLA)	Application, Development	Develop and demonstrate large aperture antenna (6 to 10 m) with wide bandwidth for: 1. Communication Link Array 2. Radar 3. Radiometer	Users requiring high data rates: Communications, Radio-Navig., Remote Sensing, Rad. Astronomy, Atmosph. Physics Measure at RF	Large payload capacity; eases otherwise severe constraints on physical parameters and operator performance - available for integration with other shuttle experiments	Moderate: Much larger data rates and higher beam resolutions. Benefit to Communications and Navigation, large data rates for dumping data in short time	Early: Preliminary 10m x 10m array designs by HAC; Circuit development required; 1980 evaluation flight achievable
2	Microwave Power Transfer	Development, Test Platform	High power array for transfer of solar power.	Military developing countries, government, industry remote areas, electrical utilities	Base for testing effectiveness of module control, pilot beam (ground) steering, array distortion correction with pilot beam	Moderate: Solar energy transfer	Early: In Definition phase; No hardware developed
3	Antenna Range Experiment (ARE)	Application, Operational Evaluation	Provide standard far field, multipath free, RF source for absolute antenna gain and pattern measurements	All large antenna users: Military Communications, Research Sta., Radio Astron., Electronic Industries Association	Integrate with other planned experiments to minimize added equipment; will utilize antenna pointing capability; low cost for demonstration	Moderate: Benefit to users of large ground antennas: Commercial, Military, NASA, Radio Astronomy Can check antennas quickly in-place	Mature: Uses state-of-art equipment and technology; techniques developed
4	Cooperative Surveillance by Spaceborne Radar (CSR)	Application	Survey territorial waters, pollution, icebergs, search and rescue, provide navigation information	USCG	Provides repetitive earth viewing for mission evaluation and operation in real time; evaluation for free-flyer	Moderate: Can use aircraft but limited in coverage. Uses: Law enforcement, navigation, SAR, hazard warning, maintain integrity in territorial waters	Early: Techniques to be developed; Hardware state-of-the-art
5	NAVSTAR/GPS (GPS)	Development, Navigation Applications	Provide range and position location information from NAVSTAR satellite system	Shuttle missions, others requiring high accuracy in location, velocity, attitude	Shuttle star tracker and ground truth reference can provide evaluation and operation in real time; evaluation for free-flyer	Low: Required by experiments with high accuracy specifications for location, velocity, attitude	Early: Definition Phase, Hardware state-of-the-art
6	Attitude and Position Interferometer Experiment	Application, Development	Demonstrate: (1) Spaceborne interferometer for fixed and moving beacons at earth surface; (2) Assess atmospheric effects on propagation	Surface and near surface vehicle navigation; search and rescue; reference meteorological aid, traffic control information	Facility for evaluating performance with typical user vehicles; provide flexibility for optimizing parameters using on-board monitor and control	Low: Depends on user requirements for very high accuracy in earth and near earth systems navigations	Early: Definition Phase, Hardware state-of-the-art
7	Open Vacuum Tube Experiment	Development	Obtain extended life data for high power TWT/KLYSTRONS using open envelope to permit outgassing to escape from interior; evaluate direct cooling of collector into space	Spacecraft with high RF power experiments; Direct broadcast, solar power transfer	Manual control used to optimize experiment and accommodate unexpected circumstances; on site observation; mission specialist perform tasks difficult to automate	Low: Experiments could be done in laboratory environment	Mature: Definition study of experiment complete; Hardware to be developed

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OF POOR QUALITY

Of the eight missions in Category A, six fall within microwave communications technology and two are concerned with processing of data prior to transmission. Several of the missions use similar equipment and could be designed to share the same equipment. For example, the basic EEE antennas/receivers can be designed to accommodate the DCMB, MWE and SCPL. Similarly, the BWCM mission can be applied to reduce data from AMPA, EEE, and other high data rate missions, e.g., Thematic Mapper and SAR.

The objectives of the COMM-NAV missions are to develop sensors and techniques that can be applied to low-orbit and synchronous-orbit satellites. Operational experience data acquired from these missions will be supplied to users for future communications systems design and where applicable, will be used to design Free-Flyer satellites. The use of the Shuttle for development of these missions provides an in-situ space laboratory and environment from which operational experience can be obtained. The short time span for missions allows mission data evaluation and reconfiguration. For the AMPA, LDASE and EEE the microwave equipment is complex and the Shuttle offers both the volume and weight capacity to conduct the missions. For DCMB and SCPL, the Shuttle offers a space platform and wide field of view from which to collect data from numerous and widely separated data transmitters. Shuttle based experiments such as the Thematic Mapper and SAR offer the high data rate in-situ source for evaluation of the BWCM in an actual communications link. Each of the missions uses the man on-board for mission operation and evaluation, and management of data.

The characteristics of the Shuttle that are beneficial to the COMM-NAV missions are:

1. Large weight and payload capacity (AMPA, EEE, LDASE)
2. Large power and data storage (AMPA, EEE, DCMB)
3. Recoverability (All Missions)
4. Orbit Selection (AMPA, EEE, DCMB, MWE, SCPL)
5. Space Platform Field of View (AMPA, EEE, DCMB, MWE, SCPL)
6. High Data Rate Sources (BWCM, DCE)
7. Man On-Board (All Missions)

## COMM-NAV Missions

### Adaptive Multibeam Phased Array (AMPA)

#### OBJECTIVE

The basic objective of the AMPA experiment is to develop an array sensor and demonstrate the techniques required to provide a multibeam array antenna that offers maximum gain and beam steering flexibility needed to communicate with multiple low cost ground terminals. Techniques to be developed include frequency reuse through Space Division Multiple Access/Time Division Multiple Access (SDMA/TDMA) techniques and multi-user communication with the multibeam capability.

A second objective of the AMPA experiment is to provide the sensor development and techniques demonstration required for subsequent Free-Flyer AMPA systems. Data to be obtained from this experiment are 1) beam steering capabilities, 2) multipath parameters, 3) interference rejection capabilities, 4) signal level requirements, 5) bit error rates, and other operational data needed to design and implement an advanced AMPA.

#### JUSTIFICATION

The implementation of low cost ground terminals and optimum use of allocated frequency bands are required for maximum cost effective use of satellite communications systems. Key to this mission is a phased array antenna which has the capability of pointing individual beams at selected ground stations, and when required, to locate and steer a beam to a specific ground station, thereby optimizing the power directed to a ground terminal. The AMPA mission will provide the antenna and systems technology to allow reduction of ground terminal performance, and thereby costs, and to employ frequency reuse techniques. The Shuttle provides the high altitude base to apply SDMA techniques and provide for many users. Development techniques and operational data acquired on Shuttle missions will provide a basis for advanced AMPA designs for Free-Flyers and advanced satellite communications systems.

Applications of the AMPA include communications with maritime, aeronautical and land mobile terminals, data collection, disaster warning, search and rescue, etc., where large numbers of terminals are used. Satellite altitude provides large area coverage for these terminals, and with optimization of power from the spacecraft, effective communication and data collection can be established with low cost minimum performance terminals.

#### DESCRIPTION

The AMPA mission will be demonstrated by establishing several communications links between the spaceborne antenna and widely spaced ground terminals. These

links will be set up to provide data to demonstrate the required signal levels, to demonstrate steering capabilities of the antenna, and to implement frequency reuse techniques such as SDMA/TDMA.

The proposed AMPA is a 3 x 3 meter phased array at L-band (1.5 GHz) and two 0.3 x 0.3 meter arrays at Ku-band (12/14 GHz). Early experiments are expected to use the L-band array. Transmit/receive modules and beam steering elements will be mounted in the Shuttle bay.

A phase A feasibility and preliminary definition study has been completed and a follow-on study is underway. Breadboard specifications for the Shuttle AMPA hardware is scheduled for the end of 1976.

## Bandwidth Compressive Modulation

### OBJECTIVE:

The objective of this experiment is to measure the statistical and operational performance characteristics of experimental communication links that use uncoded or coded multiple phase and amplitude shift keyed digital modulation techniques to conserve RF bandwidth while permitting increased data rates. Specifically, it is desired to measure performance as a function of radio frequency, transmission medium effects such as weather and atmospheric turbulence, short term scintillation, multipath and doppler effects, and orbit acquisition and thresholding effects. The performance to be measured is multi-faceted and includes information bit error rates, error pattern statistics, imperfect synchronization losses, and subjective effects associated with voice or video data. Also to be studied are the operational difficulties involved with each configuration.

This experiment will serve as a demonstration of the bandwidth compressive modulation technique and its utility, as well as a means of space qualifying the hardware components.

### JUSTIFICATION:

The needs for high data rate digital communications for information networks are placing increasing demands on radio frequency allocations. In the past when this occurred, new frequency bands were simply allocated. This cannot continue, however, because of spiraling costs and an ultimate limit on how much useful frequency is available. It is rapidly becoming necessary that more efficient forms of modulation be employed for both the new and the old allocations. Modulation/demodulation techniques such as uncoded or decoded multiple phase and amplitude shift keying have the potential for achieving bandwidth gains at a moderate cost in signaling efficiency or RF power utilization. They are thus applicable to satellite information network designs.

Ultimate application of the experiment results will be factored into information networks being developed or considered for various civil users under the auspices of Department of Health, Education and Welfare, Department of Justice, and NASA. These information networks will be used for exchange of medical information, educational information, criminal data, business data, and perhaps mail.

The Space Shuttle Laboratory provides a flexible means for conducting flight experiments on future satellite bandwidth conserving digital modulation systems in order to assess their relative performance under conditions which cannot be satisfactorily simulated by either ground based laboratories or aircraft flights. The more complex the modulation structure and its associated receiver (which is the case here), the more sensitive is its performance to signal-perturbing conditions, especially time-varying ones

(weather, atmospheric turbulence, and scintillation). The Spacelab permits astronaut manipulation and laboratory-type equipment to be used. The uniqueness of the on-board hardware precludes inexpensive unmanned satellites or transponding through existing satellites.

#### DESCRIPTION

Demonstration of the Bandwidth Compression Modulation Experiment involves establishing one-way links from the Spacelab to ground stations, and two way data links between ground stations via transponders in the Spacelab. Specific types of test data will be transmitted for the purpose of measuring error characteristics. The links will use various modulation forms including uncoded or coded phase shift keying, multiple phase shift keying, and multiple phase-and-amplitude shift keying.

The RF equipment will be implemented from modular laboratory type equipment that could be readily configured and adjusted by an astronaut for each modulation/detection technique. The equipment will include modulators and demodulators, a modulator transmitter-receiver, antennas, and test and calibration instrumentation.

The experiment hardware has been extensively analyzed and simulated, and is under construction.

## Data Collection Multibeam (DCMB)

### OBJECTIVE

The objectives of the DCMB mission are to develop a sensor, demonstrate a data collection technique and establish an operational system to monitor multiple low cost remote monitoring stations. Sensor development is to include a UHF multibeam array antenna and a coded data receivers/processor to selectively monitor individual stations. Techniques for handling multiple data inputs are to be demonstrated, and techniques for distributing large quantities of data are to be developed. The ultimate goal for the mission is to develop an operational system that will function from repetitive Shuttle flights, or a Free-Flyer low orbit satellite.

### JUSTIFICATION

The DCMB mission provides a low cost means for monitoring remotely located ground transmitters. These transmitters could be environment monitors, wild-life migration monitors, search and rescue, marine data, disaster warning, etc. A low orbit satellite mission offers a wide angle field of view, allowing coverage for large areas, and a means for monitoring individual data inputs by sharing the antenna beams and coding the monitor transmitters. Demonstration of this mission provides a basis for additional Shuttle flights and provides design and operational data for a Free-Flyer low orbit satellite. Information obtained from the mission could be used by the Department of Commerce, Department of Agriculture, NOAA and other government agencies.

### DESCRIPTION

The DCMB mission includes sensor development, techniques demonstration and operational system applications. The mission is designed to provide operational experience on a data collection technique for monitoring large numbers of remotely located ground based stations. Data collection will include inputs from fixed and moving stations. The keys to the mission are a multibeam antenna which provides multiple fan beams to cover a large area, and coded data inputs from ground transmitters to avoid interference between data inputs. Experiments will be conducted using 400 MHz ground transmitters. Data from the mission will be transmitted to a central ground control station for processing. During the mission, the on-board specialist will assist in operating the experiment and assessing the quality of data.

This experiment is essentially still in the conceptual stage; however, dependent upon the design of the EEE hardware, a common antenna array may be possible. In this case, the maturity of the DCMB experiment would be sufficiently advanced to make an early Shuttle flight a possibility.

## Data Compression Experiments For Shuttle/Spacelab (DCE)

### OBJECTIVE

The primary objective of this mission is to develop and demonstrate techniques for compressing video data, and thereby reduce the video transmission data rate and required Communications link RF bandwidth. A second objective is to implement a Spacelab to ground real-time television link. Both objectives are in support of Spacelab missions which have data rates that exceed the on-board processing the standard television link capability, and require man-in-the-loop observation.

### JUSTIFICATION

A number of experiments are being planned in various applications disciplines that will require on-board processing and display of extracted information and images. In some cases, a real-time display will be required by the Spacelab equipment operator so that he may make the necessary evaluation and decisions to operate the experiment at optimum efficiency in a seven-day mission. In other cases, this equipment operator may be required to make experiment decisions based on comparisons of data or image displays. For many visible or multispectral scanner type instruments, the raw sensed data rate required to obtain the needed images for display or quick-look analysis will exceed the on-board processing capability. In each of these situations, and others to be defined, data compression could minimize the processing bottlenecks or provide a speed up in the display operation and increase the effectiveness of the "man-in-the-loop" in Spacelab.

The justification for this experiment lies primarily in its potential value to other experiments producing large quantities of video data. Experiments involving instruments such as vidicons and multi-spectral cameras can use video data compression to transmit data in real time which otherwise would have to be recorded on-board and transmitted to ground at a later time. This real time capability will allow ground based evaluation and changes to be implemented; thus optimizing the data obtained. Feasibility demonstration of video data compression can be performed in a ground based laboratory; however a Spacelab demonstration flight is required before it can confidently be included as an integral part of other experiments, and the effects of the communications link characteristics on the video data can be assessed.

### DESCRIPTION

The DCE mission will include basic video data compression equipment which encompasses the techniques and algorithms for compression. The mission will supply raw video data and a communications link for transmission of data to a ground station. The mission also requires man-in-the-loop for mission evaluation and optimum changes of mission configuration.



Techniques or algorithms for optimally compressing data depend on the characteristics of the data source and the ultimate uses of the data. For data compression to be possible, one or both of two conditions must be satisfied. The first is that the data have some structure or redundancy. By knowing something about the data structure, some degree of data compression can be accomplished without losing any of the information the data contains. Data compression that relies solely on knowledge of data structure is information preserving or error-free data compression. Information preserving compression for picture data is usually possible in the range of 2:1 to 4:1. The second condition for data compression is that the user has interest in only limited accuracy or a particular aspect of the data collected. In this case, the data of low value to the user can be discarded, resulting in much higher potential data compression ratios. Therefore, before data compression experiments can be detailed for the sensor instrument application, the instruments must be selected. For maximum effectiveness in developing the most optimum compression algorithms, compression experiments must be carefully designed and coordinated with the sensor experiment scientists.

A video compression experiment can easily be adapted to a real-time television link from the Spacelab to ground. Experiments will undoubtedly fly on Spacelab with the principal investigator on the ground and the experiment actually conducted by an equipment operator or other investigator. Consultations between the two involving the operation of a piece of hardware might require the use of real-time TV. Experimenters on Spacelab or other Shuttle-based laboratory facilities could utilize a video link to show equipment in operation, readout graphical data, and communicate with colleagues and co-experimenters on the ground. Video could be used for monitoring certain experiments from the ground, and as a teleconferencing medium to allow real-time demonstration of on-going experiments. The ground station receiving Spacelab data could transmit the video data, still in compressed form, directly to the users at their own institutions. Video compression could thus help avoid bottlenecks in data distribution on the ground. A compression experiment for a real-time video link does not require as specific a definition of Spacelab use as does the application for a sensor instrument. Compression algorithms maximally effective for television data sources can use time motion and spatial resolution tradeoffs in the design of the video processor. This experiment is under active development with a partial breadboard of the hardware in existence and being used by JPL for system tradeoffs.

## Electromagnetic Environment Experiment (EEE)

### OBJECTIVE

The primary objective of the EEE mission is to measure and characterize electromagnetic environment interference at frequencies allocated for space use, by establishing a capability for monitoring the RF spectrum in the frequency range of 0.4 to 43 GHz. An additional objective of the mission is to determine the feasibility of monitoring earth-based interference from space and to establish techniques for measurement, storage and processing of data. Sensors, demonstration techniques, and operational procedures developed in this mission will be used to develop Free-Flyers for continuous monitoring of the RF spectrum in NASA bands of interest.

### JUSTIFICATION

Since radio frequency (RF) spectrum occupancy is experiencing an exponential growth, there is a need to establish a capability for continuous RF spectrum monitoring and electromagnetic environment (EE) mapping from space. The Shuttle/Spacelab provides an opportunity to develop space-monitoring EE capability that will prove valuable both to NASA as a spectrum user, and to governmental regulatory agencies including the Federal Communications (FCC) and United Nations agencies such as the International Telecommunications Union (ITU), the U.S. Government Interdepartment Radio Advisory Committee (IRAC) and the World Administrative Radio Conference (WARC) of the ITU.

The Shuttle/Spacelab offers a unique opportunity to measure the electromagnetic environment over a short time interval, 7-30 days, analyze data rapidly, and optimize control of the experiment or data processing through the use of an on-board specialist and on-board data display equipment. Repetitive Shuttle flights also provide additional flexibility in extended experiments and mission control.

The EEE mission provides an opportunity to develop sensors to monitor the electromagnetic environment, to demonstrate techniques for detecting the various characteristics of a signal, to develop techniques for data handling and storage, and to demonstrate an operational system for continuous EE monitoring. Experience gained during this mission will be used to develop a Free-Flyer satellite for continuous monitoring of the electromagnetic environment.

### DESCRIPTION

The EEE mission includes development of a sensitive receiver to cover the frequency range of 0.4 to 43 GHz, development of techniques to detect and store various electromagnetic signals, demonstration of techniques to measure electromagnetic signals from space and development of an operational system for use with a Free-Flyer satellite system.

Sensor development includes development of an 8-band receiver that covers the frequency range of 0.4 to 43 GHz. Antennas and receivers are designed to cover selected bands of interest to NASA and are capable of detecting and analyzing signals having right hand circular polarization, left hand circular polarization and linear polarization. Signal power level, polarization, frequency and location of an emitter with respect to the Shuttle is detected and stored along with the time, and orbiter position.

Early missions are planned for launch from the Eastern Test Range at 50-57° inclination. This provides coverage for the Continental U.S. and European countries. Later missions are planned for launch from the Western Test Range at 70-90° inclination. These missions provide coverage for repetitive measurements at various times of the day and year. Techniques planned for the mission are:

- Monitoring of EE as a function of time, day, year
- Antenna scanning techniques
- Frequency scanning techniques
- Data handling techniques
- EMI mapping and display techniques

Data from the mission will be supplied to requesting agencies for environmental and scientific purposes. Feasibility and System Definition studies have been completed, further sensor definition is planned for 1976, with a Phase C & D hardware execution planned for 1978.

## Large Deployable Antenna Shuttle Experiment (LDASE)

### OBJECTIVE

The LDASE is intended to define, develop and implement the mechanical and RF functional qualification testing of a large aperture deployable reflector antenna using the Shuttle-Spacelab system. The mechanical hardware demonstration will accomplish unfurling and furling of a 30 meter diameter parabolic antenna, and measurement of the reflector surface accuracy under varying orbital and thermal conditions. The RF test will determine the quality and performance of the antenna by measuring its RF properties and will demonstrate the RF performance of a large deployable antenna in space. A user demonstration will be conducted to verify in the space environment the applicability of a large reflector antenna for one or more specific RF experiments.

### JUSTIFICATION

A number of space systems either require or could greatly benefit from the availability of large-aperture spacecraft-mounted antennas. Such large antennas will be needed in the fields of planetary probes, radiometry, communications, RFI detection, radio astronomy, and energy transmission. More generally, these classes of users can be categorized into (1) communications information transfer or (2) observation. Figure 3-5 shows how some of the present and projected space user requirements divide into these two categories as a function of user frequency and antenna aperture. Note that the communications category users generally require apertures of 20 m or less, at frequencies of L-band and higher. The most demanding requirement for communications is that of gain, and thus, communications users are typically referred to as being gain-limited. On the other hand, the observation category of users portends sizes which are generally inversely proportional to frequency. The observation user requires resolution; i.e., the footprint of the antenna beam at the point of observation must be no larger than some specified area. For this reason, observation users are typically referred to as being resolution-limited.

The user category of "communications information transfer" includes satellites for communications, applications, and broadcast purposes; Tracking and Data Relay Satellites (TDRS); and various near-earth and planetary exploration spacecraft. For example, the 1972 Space Research and Technology (SPART) study identified firm requirements for deep-space X-band antennas up to 16 m in diameter. The 1973 NASA Payload Model identified outer planet missions that require 15 m antennas for real-time transmission of television at Saturn and beyond. The ATS-6 satellite, launched in 1973, used a 9 m deployable antenna for broadcasting. Also in 1973, Technology Requirements for Post-1985 Communication Satellites identified several potential applications of spaceborne antennas ranging up to 17 m in diameter. One reason for the lack of greater antenna size requirements in this category at this time is that higher gain-power is more readily achievable by translating to higher frequencies (above 10 GHz) than by employing larger diameter antennas at lower frequencies.

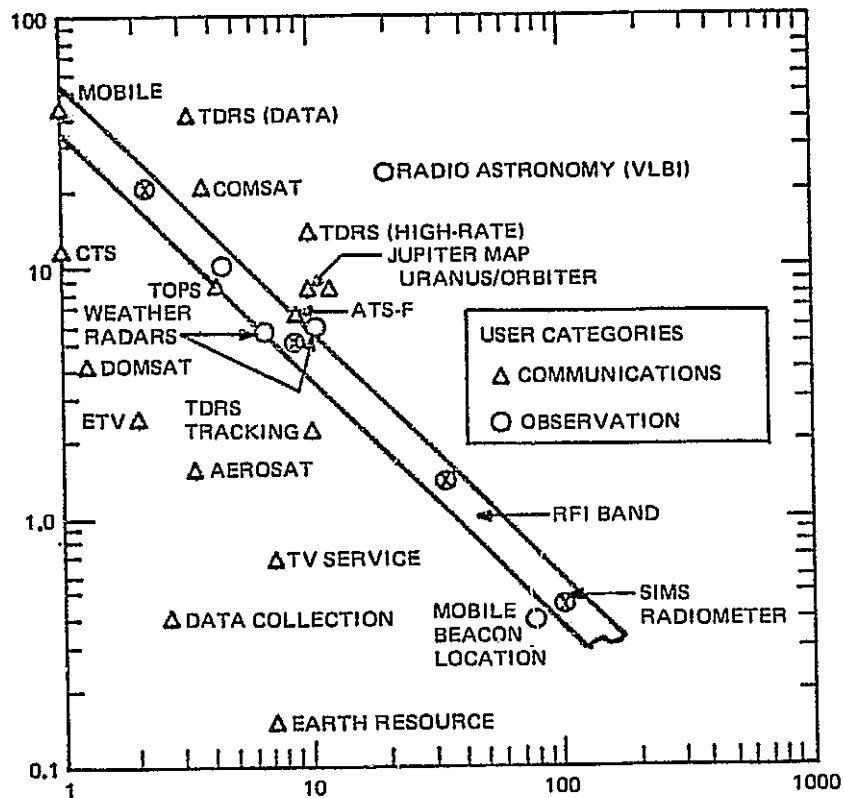


Figure 3-5. Large Spaceborne Antenna Users as a Function of Frequency and Antenna Size

The user category of "observation" comprises radio astronomy, earth observation, and atmospheric observations including the specific applications of radiometry, radio frequency interference (RFI) measurement, and weather radar observations. Shuttle workshops in 1973-75 have identified radio astronomy needs for 20 m diameter antennas at 23 GHz, weather-radar needs for 11 m diameter antennas at 4.6 GHz, and possible RFI needs for antennas as large as 70 m in diameter at 143 MHz. The Shuttle Imaging Microwave System (SIMS) envisions antennas 30 m in diameter at 1.4 GHz and 100 m at 429 MHz. The 1975 NASA Technology Forecast "Outlook for Space" hypothesizes that space antennas in earth orbit may be as large as 5000 m in diameter by the year 2000 or later. More concretely, it lists 50 m diameter needs by the year 2000 for imaging passive microwave systems. A current and ongoing JPL survey of radio astronomers and radiometers has so far revealed repeated post-1985 projections for apertures greater than 30 m at frequencies ranging up to K-band.

Thus, although the present firm requirements are for apertures up to 20 m, the need for larger sizes is clearly visible, and the demand for very large apertures will intensify as the user classes become aware that antenna technology is available to provide them.

The development of current structural concepts and designs with respect to performance, cost, weight, and packaging efficiency for large unfurlable antennas will result

in hardware without sufficient stiffness or strength for a meaningful ground test program. As a result, the antenna system must be evaluated in the zero-gravity field for which it was designed to operate. Hardware tests and a demonstration will also be required for optimization of the final mechanical concept selected. The Shuttle-Spacelab system provides the means by which experimental verification can be economically undertaken.

#### DESCRIPTION

The Large Deployable Antenna Shuttle Experiment (LDASE) is a proposed experiment to evaluate the mechanical and electrical properties of a large furlable spaceborne antenna under zero-gravity conditions. The Shuttle will be used to transport the furlable antenna into low earth orbit, where it will be deployed and tested. The integrity of the reflector surface will be measured using an amplitude-modulated laser technique. A spin-stabilized RF beacon, also carried by the Shuttle as part of the LDASE, will be ejected prior to antenna unfurlment and positioned in the same orbit to accommodate electrical performance testing of the antenna. The recommended size of antenna to be used for the LDASE is 30 m in diameter. It is not appropriate to base the size of the LDASE on specific user requirements at this time; thus, the recommended size and surface quality are based on mechanical and RF efficiency considerations germane to the demonstration of the state of the art for large furlable antenna technology for the early 1980's at the lowest possible cost. The size of the reflector selected, which generally exceeds current user requirements, is sufficient to accommodate extrapolation of mechanical performance for much larger (3X) reflectors, while representing the minimum size required for a state-of-art demonstration.

The demonstration will exploit to the maximum degree possible the functional capability of the antenna system. The entire antenna aperture will be utilized at frequencies high enough to verify and benefit from the electrical quality of the reflector. To minimize the cost of implementing the user demonstration, consideration will be given to (1) using a single focal point feed, (2) limiting the gross pointing and scanning requirements to the capability of the Shuttle attitude control and pointing systems, (3) operating only in low earth orbit to maximize Shuttle payload capability, and (4) limiting the demonstration to the minimum-time standard Shuttle mission. Fine beam pointing, if required, may be accomplished with electronically steerable antenna feeds.

It is assumed that the user demonstration will be conducted on flights subsequent to those used for mechanical and RF testing. This will (1) minimize the complexity of flight hardware for any single flight, (2) permit greater flexibility with respect to other Shuttle science payloads, and (3) amortize the total LDASE cost over several Shuttle missions.

Feasibility studies for the LDASE have been completed and detailed planning of the system definition is now underway. Flight on early Shuttle missions is considered realizable for demonstration tests.

## Millimeter Wave Communications Experiment (MWE)

### OBJECTIVE

The objective of the Millimeter Wave Communications Experiment (MWE) is to evaluate advanced wideband communications techniques in the millimeter wavelength bands centered at 20 and 30 GHz.

The MWE will provide data to permit measuring and evaluating both digital and analog communications utilizing frequency reuse techniques. The data will also permit evaluations of propagation effects and low elevation angle effects in the millimeter wavelength bands.

### JUSTIFICATION

A recent need for additional radio frequency bands has required the system designer to look at frequencies above 10 GHz in order to provide the necessary coverage. Frequency bands above 10 GHz are presently allocated for all major space services, including fixed satellites, broadcast satellite, meteorological satellite, and terrestrial services such as fixed line of sight, mobile, and radiolocation. At these frequencies, absorption and scattering caused by hydrometeors (rain, hail, or wet snow) can cause a reduction in signal level which will reduce the reliability of the link. Other effects can also be generated by precipitation events. These include depolarization, amplitude and phase scintillations, and bandwidth decoherence. All of these factors can have a degrading effect on space communications and microwave sensing at millimeter wavelengths. Many earth-space applications would benefit from the uncluttered spectrum and high data rates possible with millimeter wave communications systems. These include such applications as domestic distribution, wideband communications, remote microwave sensing, and radio navigation.

The ATS-5, ATS-6, and CTS Millimeter Wave Experiments, developed and implemented by NASA Goddard Space Flight Center, have provided the first direct measurements of earth-space links above 10 GHz from an orbiting satellite. The Shuttle MWE will continue and refine experimentation in the millimeter wave region. It is the logical extension of the past space experiments. Results of the MWE would be utilized in the development of system design requirements for NASA projects, for the development of spectrum utilization, frequency management and sharing criteria, and for the evaluation of domestic distribution and communications satellite questions under the GSFC TCS (Technical Consultation Services) Program. The data obtained from MWE will aid in the evaluation of the frequency bands above 20 GHz allocated for space applications, and provide the data base for spectrum allocation and system design in these newly emerging bands.

Shuttle-sortie mode flights have the advantage of employing large mechanically steerable antennas, astronaut controlled. A large number of geographic areas and

two-frequency spectrum areas can be observed with each mission. Follow-on manned Free-Flyer satellites could be dedicated to selected frequency bands and frequency reuse techniques. The Shuttle will permit the measurements to be made from a non-synchronous orbit, thus allowing the variables of ground station elevation angles and antenna pointing accuracy to be evaluated. Aircraft flights can collect MWE data over only a limited geographical area compared to global missions like Shuttle-sortie flights.

#### DESCRIPTION

The MWE consists of a 30 GHz uplink, 20 GHz downlink, and a 500 MHz bandwidth dual polarized transponder. Test signals will be transmitted to the Spacelab and relayed to earth terminals within the coverage zone of the vehicle. In addition, wideband data originating on the Shuttle can be relayed to the earth terminals via the 20 GHz downlink.

The MWE consists of two, earth-observation steerable antennas with a common base supported on an unpressurized Spacelab pallet section. The RF receiving system, including data processing and display electronics, will be located in conventional cabinet racks within the pressurized module. The antenna system can be deployed and retracted by remote control from the Spacelab module. Signals from the Spacelab Inertial Measurement Unit (IMU) will provide the reference for the pointing and tracking signals to the steerable antenna mounts.

The MWE will be operated in three major modes to demonstrate the feasibility of high data rate, millimeter wave, and satellite communication links.

In the "transponder mode", the MWE acts as a frequency-converting communications link. In this mode, it is planned to use two circularly polarized channels, each with a 500 MHz bandwidth, through the transponder using separate transmit and receive antennas.

In the "Spacelab mode", the payload specialist will be an active participant. For example, uplink data will be recorded, cross-correlated between channels, retransmitted via the TDRSS (limited to 50 Mbps), etc., with close coordination between the payload specialist and the responsible ground station personnel. The payload specialist may also be transmitting data, such as random generated data, TDRSS data, video data, multitone signals, and CW. Simultaneously, antenna pointing, time sharing with other experiments, and experiment monitoring will be conducted.

The "beacon mode" consists of continuously operating 20 and 30 GHz test signals (Shuttle to earth) for the evaluation of propagation and low elevation angle effects.

Preliminary Feasibility and System Definition studies have been performed, however the system design and concept have not been finalized as yet. A version of this experiment is being planned to utilize several of the EEE antennas. If this concept is adopted the MWE could be flown as an early Shuttle payload.



## Self Contained Position Location (SCPL)

### OBJECTIVE

The principal objective of the SCPL mission is to demonstrate that an improved coverage, near continuous distress monitoring system can be implemented from a low orbit satellite. This system will include sensors to detect distress signals from transmitters (ELT's, etc.) operating at 121.5, 243.0 and 406.0 MHz, on a near worldwide basis. A secondary objective of the mission is to develop techniques to locate a particular distress signal to provide detected data to key facilities, and to plan a mission profile to cover major areas of concern to navigation, etc. Ultimately, the SCPL mission could become one or more Free-Flyer satellites which form a distress monitoring system for the U.S. and other interested nations.

### JUSTIFICATION

The U.S. areas of responsibility for emergency location (EL) coverage are widely dispersed over inland, maritime and overseas regions. At present, aircraft and "inspected marine vessels" are required by law to carry emergency transmitters. The responsibility for monitoring these transmissions is not clearly defined and at best provides only a sparse coverage of the total geographical area under U.S. responsibility. The use of satellites to monitor these transmissions would improve coverage and reduce overall time for rescue in EL operations. The Shuttle provides an opportunity to demonstrate EL monitoring from a low orbit satellite. Techniques developed would be used to develop a Free-Flyer satellite EL system. The on-board specialist on the Shuttle can provide visual and aural response to distress signals, and provide assistance to mission operation.

### DESCRIPTION

The SCPL is a demonstration mission which will show the effectiveness of distress signal monitoring from space. The mission includes development of receivers for 121.5, 243.0 and 406.0 MHz, development of techniques for locating distress signals and methods of providing timely rescue information to key facilities. Area coverage is large and mission profiles must be planned to provide near continuous coverage. The mission will include monitoring over the CONUS, the major ocean areas, and some countries other than the U.S. Signals received from aircraft, ships and other vehicles will be detected, located and transmitted to nearby rescue facilities. Where appropriate emergency data can be transmitted through the TDRSS or direct to rescue facilities. Studies have been completed at GSFC to define an EL system. Hardware is state-of-the-art and available.

### Intra-Discipline Synergism and Commonality

Synergism among COMM/NAV experiments is essentially restricted to those facility type experiments such as Bandwidth Compressive Modulation, Data Compression, Attitude and Position Interferometer, and Navstar/GPS which will ultimately provide a service (data handling, position/location) to other applications experiments.

Commonality of equipment among the COMM/NAV experiments is quite prevalent. This commonality extends to antennas and receivers as well as data handling, pointing/tracking, and software. Table 3-15 lists some of the experiments which have common equipment requirements. It is evident from this table that EEE is the key experiment in this discipline with regard to providing facility type equipment which can be used for multi-purposes.

TABLE 3-15. COMM/NAV EQUIPMENT COMMONALITY

Experiment	Key Experiment	Common Equipment	Benefit/Restriction To Key Experiment
ARE	EEE	Antennas, Receivers, Data Handling (ARE Requires Transmitter, May Require Tracker)	Cost Effective/EEE Discontinued During ARE Operation Due To Tracking Requirement
DCMB	EEE	Receivers, Data Handling (DCMB Requires Modification of UHF Array, May Require Special Data Processor)	Cost Effective/EEE discontinued During DCMB Operation Due To Nadir Pointing required for DCMB
MWCE	EEE	Antennas, Data Handling (MWCE Requires Additional Antenna, Special Transponder, Tracker Using X-Y Gimbal)	Cost Effective/EEE Discontinued During MWCE Operation
Navstar/ GPS	EEE/ MMWC	Data Handling	Position Data Available/ No Restrictions To Key Experiment Except EMI

SECTION 4  
MISSION REQUIREMENTS

## SECTION 4

### MISSION REQUIREMENTS

In order to translate from the selected EVAL missions into system requirements (first step into the second phase of the study) the user needs were translated into mission requirements and sensor characterization containing information and organized into general categories of:

1. Discipline - (one of the five EVAL Disciplines)
2. Mission - (name, a total of 24 missions)
3. Observation requirements - (containing information such as orbit parameters, time of day and year that is useful for grouping of sensors for synergistic benefit)
4. Instrument requirements - (this information is useful for relating the requirements imposed on the instruments by the missions. It contains information that is useful to determine the support requirements in term of volume, weigh, field of view constraints, power, stability, data handling and any other special considerations)

This information will be used as a first step in the accommodation process of instruments on either partial, full or multiple Shuttle unpressurized pallets as well as Space-lab pressurized racks.

DISCIPLINE: WEATHER & CLIMATE (W & C 1)

MISSION: OZONE SOUNDING & MAPPING/SOLAR UV

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: 28° to 55° LATITUDE

TIME OF DAY/YEAR: DAYTIME; ANYTIME OF THE YEAR

OFFSET POINTING (DEG.): YES ; ☒ NO ;

TRACKING/SLEWING REQUIREMENTS: YES ; ☒ NO ;

STEREO REQUIREMENTS: ☒ YES ; NO ; (HROM)

SPATIAL RESOLUTION:

INSTRUMENTS:

#1 TYPE: SPECTRO-RADIOMETER

GENERIC NAME & STATUS: SBUV/TOMS (DEVELOPED, NIMBUS-G)

PARAMETERS TO BE MEASURED: VERTICAL PROFILE & TOTAL BURDEN  
OF O<sub>3</sub>; SOLAR IRRADIANCE

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
19(0.12 to 0.4 μm)

FIELD OF VIEW/BEAM WIDTH (DEG.): 90°(TOMS) NADIR VIEW; (SBUV  
DEFUSER-SOLAR VIEW)

SIZE (CM): 53 x 38 x 21 & 33 x 15 x 20

WEIGHT (KG): 24.6

AVERAGE POWER (WATTS): 20

DATA RATE (BITS/SEC) 300 & 350

POINTING ACCURACY (DEG.): 0.3

STABILITY (SEC): 100

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) SBUV DIFUSER PLATE MUST HAVE SOLAR VIEW

#2 TYPE: SPECTRO-RADIOMETER

GENERIC NAME & STATUS: HROM

PARAMETERS TO BE MEASURED: 3-D OZONE MAPPING; TOTAL BURDEN OF O<sub>3</sub>

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
13(12 BETWEEN .255 & .399  $\mu$ m) 1 .380  $\mu$ m

FIELD OF VIEW/BEAM WIDTH (DEG): 120 x 3 (NADIR VIEWING)

SIZE (CM): 60 x 25 x 25

WEIGHT (KG): 15

AVERAGE POWER (WATTS): 15

DATA RATE (BITS/SEC): 2200

POINTING ACCURACY (DEG): 0.3

STABILITY (SEC): 100

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

#3 TYPE:

GENERIC NAME & STATUS:

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

DISCIPLINE: WEATHER & CLIMATE (W & C 2)

MISSION: CLOUD CLIMATOLOGY

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: 28° to 55° LATITUDE

TIME OF DAY/YEAR: DAYTIME; ANY TIME OF THE YEAR

OFFSET POINTING (DEG.) YES ; ☒ NO ;

TRACKING/SLEWING REQUIREMENTS: YES ; ☒ NO ;

STEREO REQUIREMENTS: YES ; ☒ NO ;

SPATIAL RESOLUTION:

INSTRUMENTS

#1 TYPE: LASER RADAR SYSTEM

GENERIC NAME & STATUS: CLS (UNDER DEVELOPMENT, AAFE)

PARAMETERS TO BE MEASURED: ACTIVE CLOUD ALTITUDE, DENSITY,  
PARTICLE SIZE & H<sub>2</sub>O VAPOR CONTENT

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
(0.55 TO 1.06  $\mu$ m)

FIELD OF VIEW/BEAM WIDTH (DEG.): 0.001 (EARTH VIEWING)

SIZE (CM): TRANSMITTER: 76x51x26; RECEIVER: 127 x 97 DIAM.

WEIGHT (KG): TRANSMITTER; 265; RECEIVER

AVERAGE POWER (WATTS): 1000

DATA RATE (BITS/SEC): 1000

POINTING ACCURACY (DEG.): 0.005

STABILITY (SEC): 0.4

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

#2 TYPE: PASSIVE RADIOMETER

GENERIC NAME & STATUS: CPR (UNDER DEVELOPMENT/AAFE)

PARAMETERS TO BE MEASURED: PASSIVE CLOUD ALTITUDE, DENSITY,  
PARTICLE SIZE & H<sub>2</sub>O VAPOR CONCENTRATION

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
8 (VIS & NIR)

FIELD OF VIEW/BEAM WIDTH (DEG): 90° (EARTH VIEWING)

SIZE (CM): 81 x 25 x 36

WEIGHT (KG): 187

AVERAGE POWER (WATTS): 25

DATA RATE (BITS/SEC): 500K

POINTING ACCURACY (DEG): 0.2

STABILITY (SEC): 140

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

#3 TYPE:

GENERIC NAME & STATUS

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)



DISCIPLINE: WEATHER & CLIMATE (W & C 3)

MISSION: ATMOSPHERIC X-RAY EMISSION EXPERIMENT (AXEE)

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: 28° TO 55° LATITUDE

TIME OF DAY/YEAR: ANY TIME OF THE YEAR

OFFSET POINTING (DEG.): YES ; ☒ NO ;

TRACKING/SLEWING REQUIREMENTS: YES ; ☒ NO ;

STEREO REQUIREMENTS: YES ; ☒ NO ;

SPATIAL RESOLUTION:

INSTRUMENTS:

#1 TYPE: X-RAY CAMERA

GENERIC NAME & STATUS: AXEE

PARAMETERS TO BE MEASURED: MAP SPATIAL, TEMPORAL & ENERGY  
DISTRIBUTION OF X-RAYS IN THE ATMOSPHERE

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
X-RAY SENSITIVITY IN 5 TO 150 Kve RANGE

FIELD OF VIEW/BEAM WIDTH (DEG.): 90° x 360°

SIZE (CM): 44 x 44 x 35

WEIGHT (KG): 192

AVERAGE POWER (WATTS): 10.2

DATA RATE (BITS/SEC): 20 K

POINTING ACCURACY (DEG.): 0.2

STABILITY (SEC): 360

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) MANNED CONTROL

DISCIPLINE: WEATHER & CLIMATE (W & C 4)

MISSION: SOLAR ENERGY MONITOR

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: 28° TO 55° LATITUDE (ANY INCLINATION)

TIME OF DAY/YEAR: TWICE PER YEAR

OFFSET POINTING (DEG.): YES ; ☒ NO ;

TRACKING/SLEWING REQUIREMENTS YES ; ☒ NO ;

STEREO REQUIREMENTS: YES ; ☒ NO ;

SPATIAL RESOLUTION: (m)

INSTRUMENTS:

#1 TYPE: PYRHELIOMETER/SPECTROPHOTOMETER

GENERIC NAME & STATUS: ESP (ECLECTIC SATELLITE PHRMELIOMETER)  
UNDER DEVELOPMENT

PARAMETERS TO BE MEASURED: SOLAR CONSTANT, SOLAR SPECTRAL  
IRRADIANCE (UV/VIS/IR)

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
(0.25 TO 4.0  $\mu$ m)

FIELD OF VIEW/BEAM WIDTH (DEG.): 1.6° (SOLAR POINTING)

SIZE (CM): 25.5 x 28 x 15 (SENSOR); 14.3 x 34.3 x 9.0 (ELECTRONICS)

WEIGHT (KG): 13.5

AVERAGE POWER (WATTS): 3.5

DATA RATE (BITS/SEC): 320

POINTING ACCURACY (DEG.) 2.0

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC): 6000

MAXIMUM TRACKING RATE (DEG/SEC): TRACK SUN FOR 10 MINUTE  
PERIODS/ORBIT

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

DISCIPLINE: ENVIRONMENTAL QUALITY (EQ1)

MISSION: TROPOSPHERIC POLLUTION MAPPING

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: 55° LATITUDE

TIME OF DAY/YEAR: DAY/NIGHT; ANYTIME OF THE YEAR

OFFSET POINTING (DEG.): YES ; ☐ NO ;

TRACKING/SLEWING REQUIREMENTS: YES ; ☐ NO ;

STEREO REQUIREMENTS: YES ; ☐ NO ;

SPATIAL RESOLUTION: #1 24 Km; #2 24 Km; #3 4.4 Km

INSTRUMENTS:

#1 TYPE: CORRELATION INTERFEROMETER

GENERIC NAME & STATUS: CIMATS (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: VERTICAL BURDEN OF CO, CH<sub>4</sub>, N<sub>2</sub>O,  
NH<sub>3</sub>, O<sub>3</sub>, SO<sub>2</sub>, H<sub>2</sub>O

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
5 (2 TO 2.4 μm); 5 (4 TO 9 μm)

FIELD OF VIEW/BEAM WIDTH (DEG.): 7 OR 2; NADIR VIEWING

SIZE (CM): 2 PACKAGES: (60 x 35 x 38; 36 x 18 DIAM.); (50 x 50 x 20)

WEIGHT (KG): 50

AVERAGE POWER (WATTS): 180w (@28 V<sub>DC</sub>)

DATA RATE (BITS/SEC): 2916

POINTING ACCURACY (DEG.): 0.1

STABILITY (SEC): 36

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) COOLING LN<sub>2</sub> TO ± 1°C

#2 TYPE: GAS FILTER RADIOMETER

GENERIC NAME & STATUS: MAPS (DEVELOPED; NIMBUS-G)

PARAMETERS TO BE MEASURED: CO, CH<sub>4</sub>, HCOH

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
(3 TO 10  $\mu$ m)

FIELD OF VIEW/BEAM WIDTH (DEG): 7; NADIR VIEWING

SIZE (CM): 3 PACKAGES: (32 x 32 x 20); (50 x 37 DIAM.); (15 x 20 x 33)

WEIGHT (KG): 43Kg

AVERAGE POWER (WATTS): 67

DATA RATE (BITS/SEC): 840

POINTING ACCURACY (DEG): 0.3

STABILITY (SEC): 360

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.): NONE

#3 TYPE: MICHALSON INTERFEROMETER

GENERIC NAME & STATUS: HSI (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: SPECTRAL RADIANCE

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
(2 TO 9  $\mu$ m)

FIELD OF VIEW/BEAM WIDTH (DEG): 1.25 NADIR VIEWING

SIZE (CM): 40 x 40 x 20

WEIGHT (KG): 23

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC): 50K

POINTING ACCURACY (DEG): 0.06

STABILITY (SEC): 20

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

DISCIPLINE: ENVIRONMENTAL QUALITY (EQ2)

MISSION: STRATOSPHERIC POLLUTION MAPPING

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: 55° LATITUDE

TIME OF DAY/YEAR: SOLAR OCCULTATION

OFFSET POINTING (DEG.): YES ; ☒ NO ;

TRACKING/SLEWING REQUIREMENTS: YES ; ☒ NO ;

STEREO REQUIREMENTS: YES ; ☒ NO ;

SPATIAL RESOLUTION: #1; #2 24Km

INSTRUMENTS

#1 TYPE: SCANNING SPECTRAL RADIOMETER

GENERIC NAME & STATUS: LACATE (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: VERTICAL PROFILES OF O<sub>3</sub>, NO<sub>2</sub>,  
H<sub>2</sub>O, HNO<sub>3</sub>, CH<sub>4</sub>, AEROSOLS

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
10 (6.1 TO 17.5 μm)

FIELD OF VIEW/BEAM WIDTH (DEG.): +6, -5 VERTICAL; ±45° AZIMUTH;  
LIMB VIEWING

SIZE (CM): 4 PACKAGES (15x37 DIAM.); (67x35 DIAM.); (15x15x16); (10x15x16)

WEIGHT (KG): 77

AVERAGE POWER (WATTS): 50

DATA RATE (BITS/SEC): 4 K

POINTING ACCURACY (DEG.): 0.01

STABILITY (SEC): 5

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) #2 CIMATS (SAME AS EQ-1 INSTRUMENT #1)

#2 TYPE: SCANNING SPECTRAL RADIOMETER

GENERIC NAME & STATUS: MOCS (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: WATER TURBIDITY, SUSPENDED SOLIDS, ACID WASTES & MARINE ORGANISMS

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
(0.4 TO 0.7  $\mu\text{m}$ )

FIELD OF VIEW/BEAM WIDTH (DEG): 17.1°; NADIR VIEWING

SIZE (CM): 48 x 18 x 17

WEIGHT (KG): 5.7

AVERAGE POWER (WATTS): 6

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG): 0.5

STABILITY (SEC): 43

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

#3 TYPE:

GENERIC NAME & STATUS:

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

DISCIPLINE: ENVIRONMENTAL QUALITY (EQ-3)

MISSION: COASTAL ZONE POLLUTION

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: 55° LATITUDE

RIME OF DAY/YEAR: DAYTIME; ANYTIME OF THE YEAR

OFFSET POINTING (DEG.): YES ; ☒ NO ;

TRACKING/SLEWING REQUIREMENTS: YES ; ☒ NO ;

STEREO REQUIREMENTS: YES ; ☒ NO ;

SPATIAL RESOLUTION: #1; #2

INSTRUMENTS:

#1 TYPE: SCANNING SPECTRAL RADIOMETER

GENERIC NAME & STATUS: CZCS (DEVELOPED; NIMBUS-G)

PARAMETERS TO BE MEASURED: OCEAN & COASTAL ZONE WATER  
COLOR TEMPERATURE, MAP CHLOROPHYLL, SEDIMENT

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
6 (0.4-0.8  $\mu$ m & 10.5-12.5  $\mu$ m)

FIELD OF VIEW/BEAM WIDTH (DEG.):  $\pm 40^\circ$  AZIMUTH;  $\pm 1^\circ$  ELEVATION;  
NADIR VIEWING

SIZE (CM): 67 x 42 x 25

WEIGHT (KG): 27

AVERAGE POWER (WATTS): 25

DATA RATE (BITS/SEC):  $4 \times 10^6$

POINTING ACCURACY (DEG.): 0.05

STABILITY (SEC): 18

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) 100°K COOLING

#2 TYPE: SCANNING SPECTRO - RADIOMETER

GENERIC NAME & STATUS: THEMATIC MAPPER (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED:

#2 TYPE (CONTINUED)

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
7 BANDS - .42-.91 (5 BANDS) 1.55-1.75; 10.4-12.6

FIELD OF VIEW/BEAM WIDTH (DEG): 14° AZ - 2° ELEV.

SIZE (CM): 116 x 93 x 60

WEIGHT (KG): 180

AVERAGE POWER (WATTS): 100

DATA RATE (BITS/SEC):  $120 \times 10^6$

POINTING ACCURACY (DEG): 0.1

STABILITY (SEC): 6

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) COOLING REQUIRED TO 100°K; VIEW ANGLE: ±20° OFF  
NADIR POINTING

#3 TYPE: FILM CAMERA

GENERIC NAME & STATUS: LARGE FORMAT CAMERA

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
1 BAND; .4-.8  $\mu\text{m}$

FIELD OF VIEW/BEAM WIDTH (DEG): 40, CROSS TRACK; 80° ALONG TRACK

SIZE (CM): CAMERA - 81x61x117; POWER COND - 15x43x51; CONTROL  
ELECT - 30x43x69

WEIGHT (KG): CAMERA -136; POWER COND - 11, CONTROL ELECT - 34

AVERAGE POWER (WATTS): 180

DATA RATE (BITS/SEC): N/A

POINTING ACCURACY (DEG): 0.5

STABILITY (SEC): 3

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

VIEW ANGLE: NADIR VIEWING



DISCIPLINE: EARTH RESOURCES (ER-2)

MISSION: TIMBER VOLUME INVENTORY

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: OREGON, NEUMETICS, WISCONSIN,  
GEORGIA, NEW YORK/55° LATITUDE

TIME OF DAY/YEAR: HIGH SUN ANGLE/APRIL TO OCTOBER

OFFSET POINTING (DEG.): ☒ YES ; NO ; 20° MAX

TRACKING/SLEWING REQUIREMENTS: ☒ YES ; NO ;

STEREO REQUIREMENTS: ☒ YES ; NO ;

SPATIAL RESOLUTION: #1 - 10 METERS / #2 - 20 METERS

INSTRUMENTS:

#1 TYPE: FILM CAMERA

GENERIC NAME & STATUS: LARGE FORMAT CAMERA

PARAMETERS TO BE MEASURED: SPECTRAL REFLECTANCE  
OF TARGET AREAS

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
1 BAND; .4-.8  $\mu$ m

FIELD OF VIEW/BEAM WIDTH (DEG.): 40° CROSS TRACK; 80° ALONG TRACK

SIZE (CM): CAMERA - 81 x 61 x 117; POWER COND - 15 x 43 x 51;  
CONTROL ELECT - 30 x 43 x 69

WEIGHT (KG): CAMERA - 136; POWER COND - 11; CONTROL ELECT - 34

AVERAGE POWER (WATTS): 180

DATA RATE (BITS/SEC): N/A

POINTING ACCURACY (DEG.): 0.5

STABILITY (SEC): 3

DURATION OF EACH OBSERVATION (SEC): TARGET UNIQUE

MAXIMUM TRACKING RATE (DEG/SEC): T.B.D.

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

VIEW ANGLE: NADIR VIEWING

#2 TYPE: MICROWAVE RADIOMETER

GENERIC NAME & STATUS: SIMS (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: THERMAL EMISSION FROM EARTH SURFACE & ATMOSPHERE

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
11 FREQUENCIES

FIELD OF VIEW/BEAM WIDTH (DEG): 60° CROSS TRACK, 17° ALONG TRACK

SIZE (CM): 400 x 300 x 250

WEIGHT (KG): 952

AVERAGE POWER (WATTS): 930

DATA RATE (BITS/SEC):  $3 \times 10^6$

POINTING ACCURACY (DEG): 0.05

STABILITY (SEC): 36

DURATION OF EACH OBSERVATION (SEC): TARGET UNIQUE

MAXIMUM TRACKING RATE (DEG/SEC): T.B.D.

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

VIEW ANGLE: NADIR VIEWING

#3 TYPE:

GENERIC NAME & STATUS:

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC)

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

DISCIPLINE: EARTH RESOURCES (ER-3)

MISSION: URBAN & REGIONAL PLANNING

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: PHILADELPHIA, SAN FRANCISCO,  
SAN ANTONIO, KNOXVILLE, SIOUX FALLS SMSA'S

TIME OF DAY/YEAR: HIGH SUN ANGLE/SPRING, FALL

OFFSET POINTING (DEG.) ☒ YES ; NO ; 20° MAX

TRACKING/SLEWING REQUIREMENTS: ☒ YES ; NO ;

STEREO REQUIREMENTS: YES ; ☒ NO ;

SPATIAL RESOLUTION: #1 - 20 METERS / #2 - 10 METERS

INSTRUMENTS:

#1 TYPE:

GENERIC NAME & STATUS: THEMATIC MAPPER (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

7 BANDS - .42-.91 (5 BANDS) - 1.55-1.75; 10.4-12.6

FIELD OF VIEW/BEAM WIDTH (DEG.): 14° AZ - 2° ELEV.

SIZE (CM): 116 x 93 x 60

WEIGHT (KG): 180

AVERAGE POWER (WATTS): 100

DATA RATE (BITS/SEC):  $120 \times 10^6$

POINTING ACCURACY (DEG.): 0.1

STABILITY (SEC): 6

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) COOLING REQUIRED TO 100°K

VIEW ANGLE: ±20° OFF NADIR POINTING

#2 TYPE: MICROWAVE RADIOMETER

GENERIC NAME & STATUS: SIMS (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: THERMAL EMISSION FROM EARTH SURFACE & ATMOSPHERE

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
11 FREQUENCIES

FIELD OF VIEW/BEAM WIDTH (DEG): 60° CROSS-TRACK, 17° ALONG-TRACK

SIZE (CM): 400 x 300 x 250

WEIGHT (KG): 952

AVERAGE POWER (WATTS): 930

DATA RATE (BITS/SEC):  $3 \times 10^6$

POINTING ACCURACY (DEG): 0.50

STABILITY (SEC): 36

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

VIEW ANGLE: NADIR VIEWING

#3 TYPE:

GENERIC NAME & STATUS:

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

DISCIPLINE: EARTH RESOURCES (ER-4)

MISSION: MINERAL EXPLORATION

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: PRIME AREAS "COPPER BELT" OF SOUTHWESTERN US INCLUDING PORTIONS OF ARIZ., N. MEX., UTAH, COL. AND AREAS OF IDAHO AND WYOMING. 55° LATITUDE. SECONDARY AREAS: TBD

TIME OF DAY/YEAR: LOW SUN ANGLE/QUARTERLY COVERAGE

OFFSET POINTING (DEG.): YES ; NO ; 20' MAX

TRACKING/SLEWING REQUIREMENTS: YES ; NO ;

STEREO REQUIREMENTS: YES ; NO ;

SPATIAL RESOLUTION: #1 - 20 METERS, #2 - 20 METERS, #3 - 10 METERS

INSTRUMENTS:

#1 TYPE: ACTIVE MICROWAVE IMAGING RADAR

GENERIC NAME & STATUS: SAR (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: REFLECTED MICROWAVE RADIATION

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
X & L BANDS

FIELD OF VIEW/BEAM WIDTH (DEG.): ±5

SIZE (CM): 12 x 3 m

WEIGHT (KG): 1248

AVERAGE POWER (WATTS): 6500

DATA RATE (BITS/SEC):  $480 \times 10^6$

POINTING ACCURACY (DEG.): 0.1

STABILITY (SEC): 6

DURATION OF EACH OBSERVATION (SEC): TARGET UNIQUE

MAXIMUM TRACKING RATE (DEG/SEC): T.B.D.

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

VIEW ANGLE: 20° OFF NADIR

#2 THEMATIC MAPPER (SAME AS ER-1)

#3 LARGE FORMAT CAMERA (SAME AS ER-2)

## MISSION

Title: Tropospheric Trace Constituent Mapping

## OBJECTIVES

The goals of this mission are broad ranging, and include the following:

1. Determine whether there are changes in the radiative transfer characteristics of the atmosphere caused by changes in the minor atmospheric constituents which may have an impact on the global climate.
2. Identify the environmental constituents and parameters which may lead to inadvertent local weather modification.
3. Measure on a local basis the directly harmful pollutants which may cause damage to human health and welfare, to crops and vegetation, and to property.
4. Provide measurements of atmospheric constituents and physical properties for the development of urban air pollution prediction models.

Baseline data in the lower troposphere for  $\text{CO}$ ,  $\text{CH}_4$ ,  $\text{SO}_2$ ,  $\text{NH}_3$ ,  $\text{N}_2\text{O}$ , and  $\text{O}_3$  is to be acquired for these purposes.

## JUSTIFICATION

### 1. Radiative Transfer Changes

Changes in the radiative transfer characteristics of the atmosphere are of extreme importance since they can cause changes in the spectral flux which reaches the earth's surface and affect the thermal balance of the earth. Even minor changes in the average temperature of the earth can significantly affect crop yields, and change energy consumption. Global weather patterns could also be altered in potentially disastrous ways. To ensure that no harmful effects result from these variable constituents such as carbon dioxide and aerosols which affect the earth's heat balance must be monitored to ensure that there are no long term trends occurring which may be potentially harmful.

### 2. Weather Modification

Inadvertent weather modification is a local phenomenon which may occur in the vicinity of urban areas due to urban aerosol generation and increased thermal emission. Local thermal anomalies may cause local oxidant concentrations and modified rainfall patterns. Shuttle flight observations can provide early diagnostic data in this regard because of its ability to sample many widely separated local areas.

#2 TYPE (CONTINUED)

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
1 BAND; .4-.8  $\mu\text{m}$   
FIELD OF VIEW/BEAM WIDTH (DEG): 40° CROSS TRACK; 80° ALONG TRACK  
SIZE (CM): CAMERA - 81x61x117; POWER COND - 15x43x51; CONTROL  
ELECT. - 30x43x69  
WEIGHT (KG): CAMERA - 136; POWER COND - 11; CONTROL ELECT - 34  
AVERAGE POWER (WATTS): 180  
DATA RATE (BITS/SEC): N/A  
POINTING ACCURACY (DEG): 0.5  
STABILITY (SEC): 3  
DURATION OF EACH OBSERVATION (SEC):  
MAXIMUM TRACKING RATE (DEG/SEC):  
SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)  
VIEW ANGLE: NADIR VIEWING

#3 TYPE: ACTIVE MICROWAVE IMAGING RADAR

GENERIC NAME & STATUS: SAR  
PARAMETERS TO BE MEASURED:  
SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
X & L BANDS  
FIELD OF VIEW/BEAM WIDTH (DEG):  $\pm 5$   
SIZE (CM): 12 x 3 m  
WEIGHT (KG): 1248  
AVERAGE POWER (WATTS): 6500  
DATA RATE (BITS/SEC):  $480 \times 10^6$   
POINTING ACCURACY (DEG): 0.1  
STABILITY (SEC): 6  
DURATION OF EACH OBSERVATION (SEC):  
MAXIMUM TRACKING RATE (DEG/SEC):  
SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)  
VIEW ANGLE: 20° OFF NADIR

DISCIPLINE: EARTH RESOURCES (ER-6)

MISSION: RANGE INVENTORY

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: SOUTHWEST & WEST U.S./55°  
LATITUDE

TIME OF DAY/YEAR: HIGH SUN ANGLE/SPECIFIC PERIODS OF RANGE  
DEVELOPMENT

OFFSET POINTING (DEG.): YES ; NO ; 20° MAX

TRACKING/SLEWING REQUIREMENTS: YES ; NO ;

STEREO REQUIREMENTS: YES ; NO ;

SPATIAL RESOLUTION: #1 - 20 METERS, #2 - 1/2 - 100 KM

INSTRUMENTS:

#1 TYPE: SCANNING SPECTRO - RADIOMETER

GENERIC NAME & STATUS: THEMATIC MAPPER (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
7 BANDS - .42-.91 (5 BANDS) - 1.65-1.75; 10.4-12.6

FIELD OF VIEW/BEAM WIDTH (DEG.): 14° AZ - 2° ELEV.

SIZE (CM): 116 x 93 x 60

WEIGHT (KG): 180

AVERAGE POWER (WATTS): 100

DATA RATE (BITS/SEC): 120 x 10<sup>6</sup>

POINTING ACCURACY (DEG.): 0.1

STABILITY (SEC): 6

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) COOLING REQUIRED TO 100°K

VIEW ANGLE: ±20° OFF NADIR POINTING

#2 TYPE: MICROWAVE RADIOMETER

GENERIC NAME & STATUS: SIMS (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: THERMAL EMISSION FROM EARTH  
SURFACE & ATMOSPHERE



#2 TYPE (CONTINUED)

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

11 FREQUENCIES

FIELD OF VIEW/BEAM WIDTH (DEG): 60° CROSS TRACK, 17° ALONG TRACK

SIZE (CM): 400 x 300 x 250

WEIGHT (KG): 952

AVERAGE POWER (WATTS): 930

DATA RATE (BITS/SEC):  $3 \times 10^6$

POINTING ACCURACY (DEG): 0.05

STABILITY (SEC): 36

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

VIEW ANGLE: NADIR VIEWING

#3 TYPE:

GENERIC NAME & STATUS:

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

DISCIPLINE: EARTH RESOURCES (ER-7)

MISSION: MARINE RESOURCES

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: OCEAN AREAS T.B.D./55°  
LATITUDE

TIME OF DAY/YEAR: VARIABLE/VARIABLE

OFFSET POINTING (DEG.): ☒ YES ; NO ; TBD

TRACKING/SLEWING REQUIREMENTS: ☒ YES ; NO ;

STEREO REQUIREMENTS YES ; ☒ NO ;

SPATIAL RESOLUTION: #1 - 20 METERS, #2 - 1/2 - 100 KM

INSTRUMENTS:

#1 TYPE: SCANNING SPECTRO-RADIOMETER

GENERIC NAME & STATUS: THEMATIC MAPPER (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
7 BANDS - .42-.91 (5 BANDS) - 1.55-1.75; 10.4-12.6

FIELD OF VIEW/BEAM WIDTH (DEG.): 14° AZ - 2° ELEV.

SIZE (CM): 116 x 93 x 60

WEIGHT (KG): 180

AVERAGE POWER (WATTS): 100

DATA RATE (BITS/SEC):  $120 \times 10^6$

POINTING ACCURACY (DEG.): 0.1

STABILITY (SEC): 6

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) COOLING REQUIRED TO 100°K

VIEW ANGLE: ±20° OFF NADIR POINTING

#2 TYPE: MICROWAVE RADIOMETER

GENERIC NAME & STATUS: SIMS (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: THERMAL EMISSION FROM EARTH  
SURFACE & ATMOSPHERE

#2 TYPE (CONTINUED)

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
11 FREQUENCIES

FIELD OF VIEW/BEAM WIDTH (DEG): 60° CROSS TRACK, 17° ALONG TRACK

SIZE (CM): 400 x 300 x 250

WEIGHT (KG): 952

AVERAGE POWER (WATTS): 930

DATA RATE (BITS/SEC):  $3 \times 10^6$

POINTING ACCURACY (DEG): 0.05

STABILITY (SEC): 36

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

VIEW ANGLE: NADIR VIEWING

#3 TYPE:

GENERIC NAME & STATUS:

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

DISCIPLINE: EARTH RESOURCES (ER-8)

MISSION: WATER INVENTORY

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: SOUTHWEST U.S. /55° LATITUDE

TIME OF DAY/YEAR: ANY/SPRING

OFFSET POINTING (DEG.): ☒ YES ; NO ; 20° MAX

TRACKING/SLEWING REQUIREMENTS: ☒ YES ; NO ;

STEREO REQUIREMENTS: YES ; ☒ NO ;

SPATIAL RESOLUTION: #1 - 20 METERS, #2 - 1/2 - 100 KM

INSTRUMENTS:

#1 TYPE: SCANNING SPECTRO - RADIOMETER

GENERIC NAME & STATUS: THEMATIC MAPPER (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

7 BANDS - .42-.91 (5 BANDS) - 1.55-1.75; 10.4-12.6

FIELD OF VIEW/BEAM WIDTH (DEG.): 14° AZ - 2° ELEV.

SIZE (CM): 116 x 93 x 60

WEIGHT (KG): 180

AVERAGE POWER (WATTS): 100

DATA RATE (BITS/SEC): 120 x 10<sup>6</sup>

POINTING ACCURACY (DEG.): 0.1

STABILITY (SEC): 6

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.) COOLING REQUIRED TO 100°K

VIEW ANGLE: ±20° OFF NADIR POINTING

#2 TYPE: MICROWAVE RADIOMETER

GENERIC NAME & STATUS: SIMS (UNDER DEVELOPMENT)

PARAMETERS TO BE MEASURED: THERMAL EMISSION FROM EARTH SURFACE & ATMOSPHERE

#2 TYPE (CONTINUED)

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
11 FREQUENCIES

FIELD OF VIEW/BEAM WIDTH (DEG): 60° CROSS TRACK, 17° ALONG TRACK

SIZE (CM): 400 x 300 x 250

WEIGHT (KG): 952

AVERAGE POWER (WATTS): 930

DATA RATE (BITS/SEC):  $3 \times 10^6$

POINTING ACCURACY (DEG): 0.05

STABILITY (SEC): 36

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

VIEW ANGLE: NADIR VIEWING

#3 TYPE:

GENERIC NAME & STATUS:

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

DISCIPLINE: EARTH & OCEAN DYNAMICS (E&OD 1)

MISSION: SEA SURFACE TEMPERATURE

OBSERVATION: MICROWAVE RADIOMETRIC MAPPING OF SEA SURFACE TEMPERATURE

TARGET LOCATION & ORBIT INCLINATION: 57° INCLINATION

TIME OF DAY/YEAR:

OFFSET POINTING (DEG.):

☒ YES ; NO ;

TRACKING/SLEWING REQUIREMENTS:

☒ YES ; NO ;

STEREO REQUIREMENTS:

YES ; ☒ NO ;

SPATIAL RESOLUTION: 5-10 KM

INSTRUMENTS:

#1 TYPE:

GENERIC NAME & STATUS:

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG.):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG.):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

#1 MICROWAVE WIND SCATTEROMETER (SAME AS E&OD - 4)

#2 SIMS (SAME AS ER-1)

#3 TYPE:

GENERIC NAME & STATUS: COASTAL ZONE COLOR SCANNER (CZCS)

PARAMETERS TO BE MEASURED: MULTISPECTRAL IMAGERY

#3 TYPE (CONTINUED)

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
5 BANDS - .4-.8  $\mu\text{m}$ ; 1 BAND - 10.5-12.5  $\mu\text{m}$   
FIELD OF VIEW/BEAM WIDTH (DEG):  $\pm 40$  AZIMUTH, 1 ELEVATION  
SIZE (CM): 67 x 42 x 25  
WEIGHT (KG): 27  
AVERAGE POWER (WATTS): 25  
DATA RATE (BITS/SEC):  $4 \times 10^6$   
POINTING ACCURACY (DEG): .05  
STABILITY (SEC): 18  
DURATION OF EACH OBSERVATION (SEC):  
MAXIMUM TRACKING RATE (DEG/SEC):  
SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)  
VIEW ANGLE: NADIR VIEWING

#4 TYPE:

GENERIC NAME & STATUS:  
PARAMETERS TO BE MEASURED:  
SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
FIELD OF VIEW/BEAM WIDTH (DEG):  
SIZE (CM):  
WEIGHT (KG):  
AVERAGE POWER (WATTS):  
DATA RATE (BITS/SEC):  
POINTING ACCURACY (DEG):  
STABILITY (SEC):  
DURATION OF EACH OBSERVATION (SEC):  
MAXIMUM TRACKING RATE (DEG/SEC):  
SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

DISCIPLINE: EARTH & OCEAN DYNAMICS (E&OD 2)

MISSION: CRUSTAL MOTIONS MONITORING

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION:

TIME OF DAY/YEAR:

OFFSET POINTING (DEG.):

(YES) ; NO ;

TRACKING/SLEWING REQUIREMENTS:

(YES) ; NO ;

STEREO REQUIREMENTS:

YES ; NO ;

SPATIAL RESOLUTION:

INSTRUMENTS:

#1 TYPE: ACTIVE LASER

GENERIC NAME & STATUS: SPACEBORNE LASER RANGING SYSTEM (SLRS)

PARAMETERS TO BE MEASURED: RANGE TO GRID OF RETROREFLECTORS

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):

1 (1.06  $\mu\text{m}$ )

FIELD OF VIEW/BEAM WIDTH (DEG.): 0.03

SIZE (CM): INSTRUMENT - 82 x 57 x 36; ELECTRONICS - 0.1 m<sup>3</sup>

WEIGHT (KG): PALLET - 60; PRESSURIZED MOD - 200

AVERAGE POWER (WATTS): 250

DATA RATE (BITS/SEC): 50 x 10<sup>3</sup>

POINTING ACCURACY (DEG.): .01

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC): 10

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

VIEW ANGLE:  $\pm 65^\circ$  OFFSET POINTING FROM NADIR



DISCIPLINE: EARTH & OCEAN DYNAMICS (E&OD 3)

MISSION: OCEAN CURRENT EXPERIMENT

OBSERVATION: MULTI-SENSOR SIGNATURE FOR MAPPING OCEAN CURRENTS

TARGET LOCATION & ORBIT INCLINATION:

TIME OF DAY/YEAR:

OFFSET POINTING (DEG.): YES ; NO ;

TRACKING/SLEWING REQUIREMENTS: YES ; NO ;

STEREO REQUIREMENTS: YES ; NO ;

SPATIAL RESOLUTION:

INSTRUMENTS:

#1 TYPE: MICROWAVE ALTIMETER

GENERIC NAME & STATUS: PULSE COMPRESSION RADAR ALTIMETER

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
13.9 GHz

FIELD OF VIEW/BEAM WIDTH (DEG.): 1.5

SIZE (CM):

WEIGHT (KG): 45.4

AVERAGE POWER (WATTS): 125

DATA RATE (BITS/SEC):  $8 \times 10^3$

POINTING ACCURACY (DEG.): 0.5

STABILITY (SEC): 125

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

VIEW ANGLE: NADIR VIEWING

#2 SIMS (SAME AS ER-1)

#3 CZCS (SAME AS E&OD-1)

#4 SAR (SAME AS FR-4)

#5 TYPE: FILM CAMERA

GENERIC NAME & STATUS: MULTISPECTRAL CAMERA - S190A (FLOWN ON SKYLAB)

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)  
6 BANDS (.4-9  $\mu\text{m}$ )

FIELD OF VIEW/BEAM WIDTH (DEG): 20 x 20

SIZE (CM): CAMERA - 45 x 65 x 72; ELECTRONICS - 31 x 46 x 46

WEIGHT (KG): CAMERA - 109; ELECTRONICS - 34

AVERAGE POWER (WATTS): 200

DATA RATE (BITS/SEC): N/A

POINTING ACCURACY (DEG): 0.5

STABILITY ( $\widehat{\text{SEC}}$ ): 3

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

VIEW ANGLE: NADIR VIEWING

#6 TYPE:

GENERIC NAME & STATUS

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS)

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY ( $\widehat{\text{SEC}}$ ):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC)

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

DISCIPLINE: EARTH & OCEAN DYNAMICS (E&OD 4)

MISSION: OCEAN WAVES EXPERIMENT

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION:

TIME OF DAY/YEAR:

OFFSET POINTING (DEG.): YES ; NO ;

TRACKING/SLEWING REQUIREMENTS: YES ; NO ;

STEREO REQUIREMENTS: YES ; NO ;

SPATIAL RESOLUTION:

INSTRUMENTS:

#1 TYPE: MICROWAVE SCATTEROMETER

GENERIC NAME & STATUS: MICROWAVE WIND SCATTEROMETER (SEASAT)

PARAMETERS TO BE MEASURED: WIND SPEED (OR FRICTION VELOCITY),  
AND DIRECTION

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
Ku BAND

FIELD OF VIEW/BEAM WIDTH (DEG.): 25 x 0.5

SIZE (CM): ANTENNA (4 EACH) - 300 x 17 x 15; ELECTRONICS - 100 x 41 x 35

WEIGHT (KG): ANTENNA - 55; ELECTRONICS - 80

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG.): .05

STABILITY (SEC): 18

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

VIEW ANGLE:  $\pm 46^\circ$  FROM NADIR

#2 PCRA (SAME AS E&OD-3)

#3 SIMS (SAME AS ER-1)

#4 LARGE FORMAT CAMERA (SAME AS ER-2)

#5 TYPE:

GENERIC NAME & STATUS: HF BISTATIC RADAR

PARAMETERS TO BE MEASURED: DIRECTIONAL HEIGHT SPECTRUM OF  
OCEAN GRAVITY WAVES

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
3-50 MHz

FIELD OF VIEW/BEAM WIDTH (DEG): 60

SIZE (CM): ANTENNA - 5m WHIP; ELECTRONICS -  $0.1 \text{ m}^3$

WEIGHT (KG): 3

AVERAGE POWER (WATTS): 100

DATA RATE (BITS/SEC): 200

POINTING ACCURACY (DEG.):  $\pm 20^\circ$

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

VIEW ANGLE: EARTH VIEWING

#6 TYPE:

GENERIC NAME & STATUS: MICROWAVE DIRECTIONAL SPECTROMETER  
(PAPER DESIGN)

PARAMETERS TO BE MEASURED: COMINANT WAVELENGTH AND DIRECTION

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

#7 TYPE:

GENERIC NAME & STATUS: WAVE MOTION SENSOR

PARAMETERS TO BE MEASURED: RMS SURFACE VERTICAL VELOCITY

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
14 GHz

FIELD OF VIEW/BEAM WIDTH (DEG): 3

SIZE (CM): ANTENNA - 1m PARABOLIC DISH & FIVE 0.5 m DISHES;  
ELECTRONICS - .2m<sup>3</sup>

WEIGHT (KG): 91

AVERAGE POWER (WATTS): 90

DATA RATE (BITS/SEC): 10<sup>3</sup>

POINTING ACCURACY (DEG): 0.1

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) ANTENNAS ON 12m BOOM ALONG FLIGHT VECTOR

VIEW ANGLE: NADIR VIEWING

#8 TYPE:

GENERIC NAME & STATUS:

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):

FIELD OF VIEW/BEAM WIDTH (DEG):

SIZE (CM):

WEIGHT (KG):

AVERAGE POWER (WATTS):

DATA RATE (BITS/SEC):

POINTING ACCURACY (DEG):

STABILITY (SEC):

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.)

DISCIPLINE: EARTH & OCEAN DYNAMICS (E&OD 5)

MISSION: GEOMAGNETIC FIELD

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION:

TIME OF DAY/YEAR:

OFFSET POINTING (DEG.): YES ; NO ;

TRACKING/SLEWING REQUIREMENTS: YES ; NO ;

STEREO REQUIREMENTS: YES ; NO ;

SPATIAL RESOLUTION: 100-300 KM

INSTRUMENTS:

#1 TYPE:

GENERIC NAME & STATUS: MAGNETOMETER

PARAMETERS TO BE MEASURED:

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):

FIELD OF VIEW/BEAM WIDTH (DEG.):

SIZE (CM): MAGNETOMETER - 60x60x60; ELECTRONICS - 9x9x9; ATT.

DEFINITION SYS - 45x45x45

WEIGHT (KG): MAGNETOMETER - 9.5; ELECTRONICS-10; ATT. DEF. SYS. -21

AVERAGE POWER (WATTS): MAGNETOMETER-10; ELECTRONICS-9;  
ATT. DEF. SYS. -22

DATA RATE (BITS/SEC): MAGNETOMETER-220; ATT. DEF. SYS. - 230

POINTING ACCURACY (DEG.): .005

STABILITY (SEC): 10

DURATION OF EACH OBSERVATION (SEC):

MAXIMUM TRACKING RATE (DEG/SEC):

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) BOOM DEPLOYED 10-30 m LENGTH

DISCIPLINE: COMMUNICATION/NAVIGATION (CN-1)

MISSION: MILLIMETER WAVE COMMUNICATIONS EXPERIMENT (MWE)

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: 50 57° (OVER CONUS)

TIME OF DAY/YEAR: ANY

OFFSET POINTING (DEG.):

YES ; ☐ NO ;

TRACKING/SLEWING REQUIREMENTS:

☒ YES ; NO ; MONOPULSE  
TRACKER

STEREO REQUIREMENTS:

YES ; ☐ NO ;

SPATIAL RESOLUTION:

INSTRUMENTS:

#1 TYPE: RECEIVER/TRANSMITTER, MILLIMETER WAVE

GENERIC NAME & STATUS: TRANSPONDER, STATE OF THE ART DESIGN

PARAMETERS TO BE MEASURED: PROPAGATION PHENOMENA, BIT  
ERROR RATE, CROSS POLARIZATION DISTORTION

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
20/30 GHz

FIELD OF VIEW/BEAM WIDTH (DEG.): ±70° FOV FROM NADIR: 1°  
BEAM WIDTH

SIZE (CM): 2.3M<sup>3</sup>

WEIGHT (KG): 330

AVERAGE POWER (WATTS): 660

DATA RATE (BITS/SEC): 1 MBIT/SEC

POINTING ACCURACY (DEG.): 2

STABILITY (SEC): 72

DURATION OF EACH OBSERVATION (SEC): 7 MINUTES/ORBIT

MAXIMUM TRACKING RATE (DEG/SEC): ANY

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) BEACON TRACKING

DISCIPLINE: COMMUNICATION/NAVIGATION (CN-2)

MISSION: BANDWIDTH COMPRESSION MODULATION (BWCM)

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION:

TIME OF DAY/YEAR:

OFFSET POINTING (DEG.): YES ; NO ; } N/A

TRACKING/SLEWING REQUIREMENTS: YES ; NO ; }

STEREO REQUIREMENTS: YES ; NO ; }

SPATIAL RESOLUTION:

INSTRUMENTS:

#1 TYPE: DATA PROCESSOR

GENERIC NAME & STATUS: BWCM

PARAMETERS TO BE MEASURED: N/A

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
N/A

FIELD OF VIEW/BEAM WIDTH (DEG.): N/A

SIZE (CM): 1 RACK PRESSURIZED

WEIGHT (KG): 100

AVERAGE POWER (WATTS): TBD

DATA RATE (BITS/SEC): 120 MBPS INPUT; 20-30 MBPS OUTPUT

POINTING ACCURACY (DEG.): N/A

STABILITY (SEC): N/A

DURATION OF EACH OBSERVATION (SEC): N/A

MAXIMUM TRACKING RATE (DEG/SEC): N/A

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.) MISSION FUNCTIONS WITH THEMATIC MAPPER AND/OR SYNTHETIC APERTURE RADAR TO REDUCE DATA RATE FOR TRANS-MISSION



DISCIPLINE: COMMUNICATION/NAVIGATION (CN-3)

MISSION: ELECTROMAGNETIC ENVIRONMENT EXPERIMENT

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: ANY (INITIALLY CONUS);  
INCLINATION 50-57°

TIME OF DAY/YEAR: ANY

OFFSET POINTING (DEG.): YES ; ☒ NO ; ACCOMPLISHED  
BY INSTRUMENT (SPACE ORIENTED TO NADIR)

TRACKING/SLEWING REQUIREMENTS: ☒ YES ; NO ; EEE ANTENNAS  
(6-10)°/SEC CROSS - TRACK SCAN

STEREO REQUIREMENTS: YES ; ☒ NO ;

SPATIAL RESOLUTION: NO REQUIREMENT

INSTRUMENTS:

#1 TYPE: RECEIVER

GENERIC NAME & STATUS: EEE/DEFINITION STUDY

PARAMETERS TO BE MEASURED: POWER, FREQUENCY, POLARIZATION  
OF EARTH BASED MICROWAVE SIGNALS

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
0.4 - 43 GHz

FIELD OF VIEW/BEAM WIDTH (DEG.): CONICAL PATTERN (360° AZIMUTH,  
±80 ELEVATION)

SIZE (CM): 1 PALLET UNPRESSURIZED; 1 ROCK PRESSURIZED

WEIGHT (KG): 259

AVERAGE POWER (WATTS): 525

DATA RATE (BITS/SEC) 10<sup>6</sup> MAX

POINTING ACCURACY (DEG.): 2°

STABILITY (SEC): 72

DURATION OF EACH OBSERVATION (SEC): 420 AVG

MAXIMUM TRACKING RATE (DEG/SEC): ANY

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING,  
COOLING, etc.) BOOM EXTENSION TO ELIMINATE EMI FROM SHUTTLE  
AND IMPROVE FOV

DISCIPLINE: COMMUNICATION/NAVIGATION (CN-4)

MISSION: ADAPTIVE MULTIBEAM PHASED ARRAY EXPERIMENT

OBSERVATION:

TARGET LOCATION & ORBIT INCLINATION: ANY

TIME OF DAY/YEAR: ANY

OFFSET POINTING (DEG.):

(YES) ; NO ;  $\pm 30^\circ$

TRACKING/SLEWING REQUIREMENTS:

(YES) ; NO ;  $2^\circ/\text{SECOND}$

STEREO REQUIREMENTS:

YES ; (NO) ;

SPATIAL RESOLUTION: 35Km (RADIOMETER)

INSTRUMENTS:

#1 TYPE: ADAPTIVE PHASED ARRAY ANTENNA

GENERIC NAME & STATUS: AMPA (CONCEPT DEFINITION STUDY)

PARAMETERS TO BE MEASURED: SIGNAL QUALITY (e.g. SIGNAL TO NOISE, INTERFERENCE REJECTION, ETC.)

SPECTRAL BANDS/FREQUENCY (NUMBER & LOCATION OF CHANNELS):  
L & KU BANDS

FIELD OF VIEW/BEAM WIDTH (DEG.):  $5^\circ$

SIZE (CM): 300 X 300 X 50

WEIGHT (KG): 1800

AVERAGE POWER (WATTS): 600

DATA RATE (BITS/SEC): 50 KBITS/SEC & 1 MBIT/SEC

POINTING ACCURACY (DEG.):  $0.5^\circ$

STABILITY (SEC):  $180^\circ$

DURATION OF EACH OBSERVATION (SEC): 90 SECONDS PER ORBIT  
(3 ORBITS/DAY)

MAXIMUM TRACKING RATE (DEG/SEC):  $2^\circ$

SPECIAL CONSIDERATIONS (DESCRIBE; e.g., EMI, SPECIAL MOUNTING, COOLING, etc.)

SECTION 5

SENSORS

## SECTION 5

### SENSORS

Earth Observation Sensors can be classified by a unique characteristic of implementation or operation. Table 5-1 defines these classes and sub-classes.

Table 5-1. Earth Observation Sensor Classes

Classification	Sub Classes
Mechanical Imager	Image Plane Scanner Object Plane Scanner Multi-feed Antenna
Electrical Imager	Vidicon "Push Broom" Array Phased Array Radar
Film Camera	Panaramic Multi-spectral
Non-imager	Sounder Atmospheric Profiler Limb Scanner Spectrometer
Active	Microwave Radar Laser

The EVAL Instruments, given in Table 5-2, as defined to satisfy the mission requirements, cover the full range of these classifications. They are also representative of the current and projected state of the art in Earth Observation Sensors.

#### MECHANICAL IMAGER

The major purpose of mechanical imagers is to obtain two dimensional radiance maps of the earth in a number of spectral regions. These radiance maps are used for virtually all Earth Observation disciplines. In this sensor class, a portion (either a single element or line) of the scene is imaged on the detection mechanism, and scanning is accomplished by changing the portion of the scene viewed by mechanical means. Both object plane and image plane scanning techniques have been used. The state of the art of each of the sensor components is virtually at the theoretical limit so that the performance of these devices is limited primarily by size, weight, power, and

Table 5-2. EVAL Instruments

Instruments	Size, cm	Weight Kg	Power (Watt.)	Data Rate (Bts/Sec)	Field of View	View Angle	Pointing Accuracy Stability		Remarks
							(Deg)	Applitude (Sec)	
HROM (High Resolution Ozone Mapper)	60 x 25 x 25	15	15	2200	120° x 3°	Earth Viewing	0.3	100	Under Development
CMATS (Correlation Interferometer for Measurement of Atmospheric Trace Species)	60 x 35 x 38 18 x 18 x 38 50 x 50 x 20	50	180	2916	7° or 2°	No Sun View Nadir Viewing	0.1	36	AAFE
MAPS (Monitoring Air Pollution From Space)	32 x 32 x 20	43	67	840	7°	No Sun View Nadir Viewing	0.3	360	AAFE
HBI (High Speed Interferometer)	40 x 20 x 20	23	TBD	50 x 10 <sup>3</sup>	1.25°		0.06	20	Under Development
LACATE (Lower Atmospheric Composition and Temperature Experiment)	37 x 37 x 15	77	50	4 x 10 <sup>3</sup>	+6°, -5° Vert. +45° Azimuth	Horizon Viewing	0.01	5	AAFE
CZCS (Coastal Zone Color Scanner)	67 x 42 x 25	27	25	4 x 10 <sup>6</sup>	+40° Azimuth 1° Elevation	Nadir Viewing	0.05	18	Nimbus G
MOCSS (Multichannel Ocean Color Scanner)	48 x 18 x 17	5.7	6		17.1°	Nadir Viewing	0.5	43	Under Development
CPR (Cloud Physics Radiometer)	81 x 25 x 30	187	25	500 x 10 <sup>3</sup>	90°	Earth Viewing	0.2	140	AAFE
CLS (Cloud Lidar System)	<u>Transmitter</u> 76 x 51 x 26 <u>Receiver</u> 127 x 97 Dia	<u>Transmitter</u> 265 <u>Receiver</u> TBD	1000  1000	1000	0.0010	Earth Viewing	0.005	0.4	AAFE
SIMS (Shuttle Imaging Microwave System)	400 x 300 x 250	952	930	3 x 10 <sup>6</sup>	60° Cross-Track 17° Along Track	Nadir Viewing	0.05	36	Under Development

Table 5-2. EVAL Instruments (Continued)

Instruments	Size, cm	Weight, Kg	Power (Watts)	Data Rate (Bits/Sec)	Field of View	View Angle	Pointing Accuracy Stability		Remarks
							(Deg.)	Applitude (Sec)	
(Multispectral Camera)	<u>Camera</u> 45 x 65 x 72 <u>Electronics</u> 31 x 46 x 46	<u>Camera</u> 109 <u>Electronics</u> 34	200	NA	20° x 20°	Nadir Viewing	0.5	3	Skylab
LFC (Large Format Camera)	<u>Camera</u> 81 x 61 x 117 Power Cond. 15 x 43 x 51 <u>Control Elect.</u> 30 x 4" x 69	<u>Camera</u> 136 Power Cond. 11 <u>Control Elect.</u> 34	180	NA	40° Cross Track 80° Along Track	Nadir Viewing	0.5	3	Under Development
SAR (Shuttle) (X & L Bands)	12 x 3 m	1248 Kg	6500	480 x 10 <sup>6</sup>	± 5°	20° Off Nadir	0.1	6	Under Development
Magnetometer	<u>Magnetometer</u> 60 x 60 x 60 <u>Electronics</u> 9 x 9 x 9 <u>Attitude Def. Sys.</u> 45 x 45 x 45	<u>Magnetometer</u> 9.5 <u>Electronics</u> 10 <u>Attitude Def. Sys.</u> 21	Magnetometer 10 Electronics 9 Att. Def. Sys. 22	Magnetometer 220 Att. Def. Sys. 230			0.005	10	Boom Deployed 10-30m W Length Under Development
MWVS (Microwave Wind Scatterometer)	<u>Antenna</u> (1 ea) 300 x 17 15 <u>Electronics</u> 100 x 41 x 35	<u>Antenna</u> 55 <u>Electronics</u> 80			25° x 0.5°	±16° from Nadir	0.005	18	SEASAT
EEE (Electromagnetic Environment Experiment)	1.8 x 1.8 m Array 1.0 m Dish 0.5 m Dish (3)	259	525	8.3 x 10 <sup>3</sup> (avg.) To 1.0 x 10 <sup>6</sup> (max.)	1° - 30° (Rand Dependent)	Nadir Pointing ±80°	0.1	180	Single Pallet Config. UAA 239 kg 465W Spacelab 20 kg 60W Under Development
AMDA (Adaptive Multibeam. Phased Array)	<u>Antenna</u> 3 x 3 x .5m (L-Band) .4X 4X .5m (Ku-xmit) .4X 4X .5m (Ku-rev) <u>Electronics</u> .5m <sup>3</sup>	<u>Antenna</u> 1500w (L Band) 100Kg (Ku-xmit) 100Kg (Ku-rev) <u>Electronics</u> 150 Kg	500 (L Band) 300w (L Band RM) 600w (Ku Band) 800w (Standby)	50 x 10 <sup>3</sup> (L-comm) 1 x 10 <sup>3</sup> (L-Rm)	±40°	Horizon-To-Horizon	0.3	180	Under Development

Table 5-2. EVAL Instruments (Continued)

Instruments	Size, cm	Weight, Kg	Power (Watts)	Data Rate (Bits/Sec)	Field of View	View Angle	Pointing Accuracy Stability		Remarks
							(Deg)	Apptitude (Sec)	
SBUV/TOMS (Solar Backscatter UV Total Ozone Mapping Spectrom- eter)	53 x 38 x 21 33 x 15 x 20	18.9 7.7	20	300	11.3° x 11.3° (105°)	Nadir Viewing Solar View with a Diffuser Plate	0.3	100	Nimbus G
PCRA (Pulse Compression Radar Altimeter)	<u>Antenna</u> 1.0 m Para Dish	46.4	125	8 x 10 <sup>3</sup>	1.5°	Nadir Viewing	0.07	125	SEASAT
MW Antenna	<u>Pressurized</u> 1.3 m <sup>3</sup> <u>Unpressurized</u> 1.0 m <sup>3</sup>	<u>Pressurized</u> 110 Kg <u>Unpressurized</u> 220 Kg	350 @ 28VDC 250 @ 115V 60 Hz		1.3° Beam Width	Horizon to Horizon	0.05	90	Under Development
AXEE (Atmospheric X-Ray Emission Experiment)	44 x 44 x 35	192	10.2	20 x 10 <sup>3</sup>	90° x 360°	Horizon to Horizon	0.2	360	Under Development
TM (Thematic Mapper)	116 x 93 x 60	180	100	120 x 10 <sup>6</sup>	14° Azimuth 2° Elev.	±20° Off Nadir Pointing	0.1	6	Under Development
BCM (Bandwidth Compression Modulation)	<u>Antenna</u> 1 m <sup>2</sup> Parabolic Dish <u>Pressurized</u> Module 1.2 m <sup>3</sup>	<u>Antenna</u> 7 <u>Pressurized</u> Module 233	1300 WAC (400 Hz)	500	1° Beam Width	Earth Viewing		3800	Pressurized Module Inside Spacelab Module Under Development
ESP (Eclectic Satellite Pyrheliom- eter)	<u>Instrument</u> 25.5 x 28 x 15 <u>Electronics</u> 14.3 x 34.3 x 9.0	13.5	3.5	320	1.6°	Solar Pointing	2.0		AAFE
SLRS (Spaceborne Laser Ranging System)	<u>Pallet</u> 82 x 67 x 36 <u>Pressurized Module</u> 1 Rack	60	250	50 x 10 <sup>3</sup>	0.03	±65° Offset Pointing	0.01		Under Development Tracking Accuracy 0.2 mrad for 10 Seconds
HFRF (HF Bistatic Radar)	<u>Antenna</u> 5m Whip <u>Electronics</u> .08 m <sup>3</sup>	3	100	200	±60°	Earth Viewing	±20°		20 col 20 min data takes Flown on A/C
MWDWS (MW Directional Spectrometer)	<u>Antenna</u> 3X - 6M .5 M <sup>3</sup>	100	250	4 x 10 <sup>3</sup>	.5 x 1°	20°Nadir Offset	.25		Paper Design Under Development

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cost. This is not to imply that all of the components of any given instrument are at, or near, the theoretical limit. For example, many mechanically scanned imaging radiometers in the IR and visible have spatial resolutions far poorer than the theoretical diffraction limit due to photon energy limitations.

The technology developed on radar has made it unlikely that there will be any major improvement in the antenna, scan mechanisms, or electronics of purely passive systems. The mechanically scanned system offers the possibility of using multiple feeds for multiple frequencies but the area of multi-feeds requires additional effort. Adjacent feeds at the same frequency allow the simultaneous scanning of multiple lines (similar to the IR and visible multi-line scanners). As in the case of visual/IR sensors, microwave sensors can be scanned in the object plane with reflectors or by moving the whole antenna (e.g., radar) or in the image plane by moving feeds. They can also have linear, sinusoidal, or conical scan patterns similar to photon imaging sensors.

For mapping or surveying purposes, one must assume a vehicle mounted radiometer and hence a limit on the size of the antenna. Thus, there exists a tradeoff between IFOV and frequency, because of the diffraction limit. This tradeoff is not currently evident in the IR and visible because of the energy limit, but will become more important as large linear array systems come into greater use.

The Thematic Mapper, CZCS, MOCS and HROM are UV/visual/IR sensors that fall in this category. An example of a microwave mechanical imager is SIMS.

### ELECTRONIC IMAGERS

This sensor class defines a series of devices that use electronic scan techniques to read out the latent electron charge image of a scene imaged on a detection mechanism. Included in this class are devices such as Vidicons, "Pushbroom" arrays, and phased array radar.

The vidicon camera was one of the first to be used in remote sensing of the environment primarily in meteorology. The characteristics of the various kinds of electron beam readout sensors in this class are well known and the diversification of kind can be attributed in part to efforts to overcome deficiencies in an existing kind (e.g., image isocon using scattered return beam electrons rather than reflected return beam electrons as in the orthicon to reduce beam current noise).

In general terms the visual/near IR electron beam readout sensors have higher sensitivities (because of inherent integration and low photoconductor/emitter bandwidths) than single element scanners, but if one were to compare them to an equivalent two dimensional array of solid state detectors, they would in general be less sensitive because of their lower quantum efficiencies. Solid state Charge Coupled Diode (CCD) and Charge Injection Diode (CID) two dimensional arrays have been fabricated and are in use in prototype TV camera systems. Development of the technology to extend the spectral response into the infrared (8-13  $\mu\text{m}$ ) is in progress.



In "pushbroom" array sensors, a detector array is located orthogonal to the vehicle velocity vector, with the width of scan angle being determined by the length of the detector array. The principal advantage of this arrangement is that there are no moving parts required for scanning since readout along the array is accomplished electronically. Further, the spectral separation mechanism is much simpler. This technique is dependent on large (many thousands of elements) linear arrays and proper wide field of view optics. The technology for these components exists, point design studies have been completed, and breadboards are being fabricated and tested.

Phased array radar techniques are currently being developed which will provide high spatial resolution, high data rate performance. Examples of this are the Synthetic Aperture Radar (SAR), and the Adaptive Multi-beam Phased Array (AMPA).

### FILM CAMERAS

Film sensors will undoubtedly be used extensively over the next few years for earth resources observations because they provide (1) very high resolution, in essence diffraction limited; (2) simple and fast processing to achieve hard copies for the users; (3) excellent geometric accuracy with little or no processing (4) ease of storage of high density information; and (5) relatively low cost.

Film cameras have achieved a very high degree of sophistication, and are not likely to see any significant improvement in the next few years. They suffer from some drawbacks such as coarse radiometric accuracy and the difficulty of extracting radiometric data (scanning microdensitometer). Probably the most significant observation is that electronically scanned photosensors are rapidly approaching the resolution of film cameras, and already have achieved the sensitivity. It is therefore possible that film cameras may be superseded by electronic systems within the next 5 to 10 years for a large portion of the Earth Observations missions.

However, for the early Shuttle Flights, film cameras will be used to obtain large area coverage, high spatial resolution, multispectral imagery. The Large Format Camera and Multispectral Camera (S-190A) are EVAL instruments that are in this classification.

### NON-IMAGERS

This class of sensor has basically the same characteristics as the mechanical imager class (both active and passive) with the exception that there is no scan mechanism. This sensor is generally represented by the atmospheric profiler heat balance instruments, altimeters, and spectrometers.

Because of the relatively fixed field of view, the data rate requirement is not severe. Therefore, they have been used as spectrometers where the input energy is dispersed into spectral components in a continuous fashion and the output is a function of both frequency and incident amplitude. Spectrometers have been under development for

many years and cover virtually the whole spectrum from x-ray to dc. Many of the EVAL instruments fall within this classification. For example: CIMATS, MAPS, LACATE, HSI, SBUV/TOMS, Radar Altimeter, Cloud Physics Radiometer, and Atmospheric X-Ray Emission Experiment.

#### ACTIVE SENSORS

Active sensors such as microwave radar and lidar have a self contained source of illumination. Their application are many and they are probably the best candidate for the next generation of sensors. The important applications will be the measurement of the scattering in the atmosphere, soil and mineral measurements, cloud measurements, and ocean dynamic experiments. By time-gating the receiver (radiometer) a profile of scattering versus altitude may be obtained, or integrating the signal for the entire light travel time to the ground will give the total back-scatter. Turnable sources in both the visible and IR are still in the status of a growing technology.

EVAL Instruments which fall into the active sensor classification are: Cloud Lidar System, SAR, Microwave Wind Scatterometer, AMPA, Pulse Compression Radar Altimeter, and Spaceborne Laser Ranging System.

SECTION 6  
MISSION GROUPING

## SECTION 6

### MISSION GROUPING

One of the goals of the present study is to assess the degree of synergism, and its value, that can be associated with EVAL payloads. (This, along with commonality of experiment equipment, discussed in a later part of this section, are two of the key factors that will result in cost effective EVAL payloads.) For the purposes of this study, synergism is defined as the cooperative operation of experiments/missions in one or more of the following contexts:

1. Scientific return of an experiment/mission is increased because of complementary data provided by other sensors with their own missions. Examples include data which provides calibration, position determination, atmospheric conditions, etc.
2. An additional mission is possible without the addition of any new sensors through the judicious combination of two or more other missions:  $2 + 2 = 5$
3. Sensor or target adaptation for one mission is accomplished based on data provided by another mission.

The point of reference for these variants of synergism is a single sensor, or dedicated group of sensors, performing a single mission on Shuttle within a fixed budget.

Synergistic benefits can be obtained through the grouping of experiments/missions from different disciplines (e.g., Weather & Climate and Environmental Quality) as well as from within a single discipline. Preliminary groupings of experiments/missions based on synergistic enhancement of user data are presented in the following paragraphs.

A total of twenty-eight missions were selected as candidates for early Space Shuttle flights. These missions cover all five disciplines (Environmental Quality, Weather and Climate, Communication and Navigation, Earth Resources and Earth and Ocean Dynamics) and are listed in Table 6-1 with their corresponding instruments.

Table 6-2 is a chart showing EVAL missions and instruments. From this chart it can be seen that the majority of sensors have application in more than one mission, and within more than one discipline. In fact, instruments such as SIMS, Thematic Mapper, and the Large Format Camera are used with over half of the missions. The one area that appears to be an exception to this trend is Comm/Nav. While there is commonality of equipment within the discipline, the sensors essentially have application only within the Comm/Nav discipline. It should be noted that the sensors indicated in Table 6-2 have not been segregated in terms of those that are mandatory and those that are merely desirable. This differentiation will be addressed in the next phase of the study, and will be the basis for completing the payload groupings along with a detailed accommodation and compatibility analysis.

Table 6-1. Mission Identification

Discipline	Mission	Title	Sensors
Environmental Quality	EQ 1	Tropospheric Trace Constituent Mapping	CIMATS, MAPS, HSI
	EQ 2	Stratospheric Pollution Mapping	LACATE, CIMATS, SBUV/TOMS, HALOE, SER, HSI, APPS, ESP
	EQ 3	Coastal Zone Pollution	CZCS, MOCS, SIMS, LFC, TM
Weather and Climate	W&C 1	Ozone Sounding & Mapping/Solar UV	SBUV/TOMS, HRM, LACATE, HSI, MAPS, CIMATS, SER
	W&C 2	Cloud Climatology	CLS, CPR, SIMS, LFC
	W&C 3	Solar Energy Monitor	ESP
Communications and Navigation	CN 1	Propagation Experiment	MWA
	CN 2	Data Compression	BCM
	CN 3	EEE	EEE
	CN 4	AMPA	AMPA
	CN 5	Data Collection with Multibeam	EEE, AMPA
	CN 6	Antenna Range	EEE
	CN 7	Large Deployable Antenna	LDASE
	CN 8	Cooperative Surveillance Identification	EEE
Earth Resources	ER 1	World Crop Survey	TM, SIMS, SAR, LFC
	ER 2	Timber Volume Inventory	TM, LFC, SAR
	ER 3	Urban & Regional Planning	TM, LFC
	ER 4	Mineral Exploration	TM, LFC, SAR
	ER 5	Vegetation Stress	TM, LFC, SAR, SIMS
	ER 6	Range Inventory	TM, SIMS, SAR
	ER 7	Marine Resources	TM, SIMS, SAR
	ER 8	Water Inventory	TM, SIMS, SAR
Earth and Ocean Dynamics	E&OD 1	Sea Surface Temperature	MWSCAT, SIMS, CZCS, TM, LFC
	E&OD 2	Crustal Motions Monitoring	SLRS, LFC, TM
	E&OD 3	Ocean Current Experiment	PCRA, SAR, SIMS, S-193, CZCS, 2 FC, TM
	E&OD 4	Ocean Waves Experiment	PCRA, SAR, MWSCAT, LFC, HFBR, MWDWS, TM
	E&OD 5	Geomagnetic Field	Magnetometer

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Table 6-2. Instrument Commonality

	SER	HALOE	CIMATS	MAPS	HSI	LACATE	CZCS	MOCS	SBUV/TOMS	HRDM	CLS	CPR	ESP	MWA	BCM	EEE	AMPA	TM	SIMS	LFC or Photopac	SAR	MWSCAT	SLRS	PCRA	S-190 A	HFBR	MWDWS	WMS	MAGNETOMETER	LDASE
EQ 1			X	X	X						X	X						X	X	X										
EQ 2	X	X	X		X	X			X				X						X											
EQ 3							X	X										X	X	X	X				X					
W&C 1	X		X	X	X	X			X	X																				
W&C 2											X	X							X	X					X					
W&C 3													X																	
CN 1														X		X														
CN 2															X															
CN 3														X		X	X													
CN 4																X	X													
CN 5																X	X													
CN 6																X														
CN 7																														X
CN 8																X														
ER 1																		X	X	X	X									
ER 2																		X		X	X									
ER 3																		X		X	X									
ER 4																		X		X	X									
ER 5																		X	X	X	X									
ER 6																		X	X		X									
ER 7																		X	X		X									
ER 8																		X	X		X									
E&OD 1							X											X	X	X		X								
E&OD 2																		X		X			X							
E&OD 3							X	X										X	X	X	X			X			X	X	X	
E&OD 4																		X		X	X	X		X			X	X		
E&OD 5																							X							X

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Table 6-3 shows the intra-discipline as well as cross discipline missions that when combined together provide synergistic benefits in terms of enhancing information provided to the user. These synergistic missions are called the "S" missions and require a certain grouping of sensors to be operating simultaneously. The justification for these groupings is described in the next several pages. It should be noted that these groupings have been determined principally on the basis of enhanced scientific data, and that the actual accommodations and compatibility of these groupings has not been fully confirmed at this point. The groupings have been checked on a cursory basis for accommodation within the limitation of Spacelab for parameters such as total weight, load factors, mounting area, power, environmental control, data handling, and field of view. The compatibility of these groupings with other non-EVAL payloads and timelining of crew availability, power, data recording, etc., have not been considered within this study phase. These questions are key items which will be addressed in the subsequent study phase.

#### Synergistic Group S-1

The Ozone Sounding and Mapping/Solar UV experiment utilizes the SBUV/TOMS as one of the sensors. One of the primary objectives of the SBUV/TOMS on Shuttle is to obtain periodic data for use in calibrating the identical instrument which will be used on TIROS-N for ozone monitoring. Additional objectives include the effects of local contaminant sources, both natural (e.g., volcanoes) and anthropogenic (e.g., urban aerosol generation). These latter objectives are consistent with the objectives of the stratospheric environmental quality mission which include determining whether there is a depletion of the stratospheric ozone concentration due to the introduction of man-made pollutants into the stratosphere and identifying the critical constituents. Thus, the SBUV/TOMS data is valuable for both Weather and Climate and Environmental Quality mission objectives.

In addition, the objectives of the Environmental Quality - Tropospheric Pollution Mapping mission provide information useful to Weather and Climate studies. The objectives which provide interdiscipline benefits are:

1. Determine whether there are changes in the radiative transfer characteristics of the atmosphere caused by changes in the minor atmospheric constituents which may have an impact on the global climate.
2. Identify the environmental constituents and parameters which may lead to inadvertent local weather modification.

#### Synergistic Group S-2

One of the sensor outputs in the coastal zone water pollution experiment is surface temperature. Since sea surface temperature is a requirement for the earth and

Table 6-3. Synergistic Groups

Synergism	Missions	Instruments
S-1	Ozone Sounding & Mapping/Solar UV Tropospheric Trace Constituent Mapping	SBUV/TOMS, HROM, CIMATS, MAPS, HSI, LACATE, SER
S-2	Coastal Zone Pollution Sea Surface Temperature Marine Resources	CZCS, MOCS, MWSCAT, SIMS, TM, LFC
S-3	Tropospheric Trace Constituent Mapping Vegetation Stress	CIMATS, MAPS, HSI, TM, SIMS, LFC SAR
S-4	Geomagnetic Field Mineral Exploration	TM, LFC, SAR, Magnetometer
S-5	AXEE Solar Energy Monitor	AXEE, ESP
S-6	World Crop Survey Vegetation Stress Water Inventory Data Compression	TM, SIMS, LFC, SAR, BCM
S-7	Timber Volume Inventory Urban & Regional Planning Range Inventory	TM, LFC, SIMS
S-8	Propagation Experiment Cloud Climatology	MWE, CLS, CPR
S-9	Sea Surface Temperature Ocean Current Experiment Ocean Waves Experiment	MWSCAT, SIMS, CZCS, PCRA, S-190A, SAR, LFC, HFBR, MWDWS, TM, LFC



ocean dynamics mission EOD-1, the two experiments can benefit from a single measurement of sea surface temperature. Living Marine Resource Assessment may also benefit from the results of the other two missions. Coastal zone pollution will have obvious effects on the living marine life in affected areas, and sea surface temperature may be an important indicator of favorable marine life habitat.

#### Synergistic Group S-3

The tropospheric pollutant mapping experiment (EQ-1) will provide information regarding the spatial and temporal variations of pollutants which have been demonstrated to be harmful to vegetation. Correlation of the areas of vegetation stress defined by the earth resources experiment with pollutant maps produced by the tropospheric pollutant mapping experiment will permit an assessment of the extent to which pollution can affect vegetation.

#### Synergistic Group S-4

Geomagnetic Field Measurements (E&OD5) will complement the Mineral Exploration Mission (ER-4) by (1) providing indications of large-scale magnetic anomalies (200 km) that are related to major crustal and geological features which may have a high potential for mineral bearing deposits, and by (2) providing baseline regional data for background removal for detailed aeromagnetic surveys.

#### Synergistic Group S-5

The Solar Energy Monitor will provide accurate values of the total and spectral solar energy output. The Atmosphere X-ray Emission Experiment (AXEE) will make observations of solar-induced atmospheric x-rays in an attempt to correlate certain terrestrial weather events with solar activity phenomena. Thus, simultaneous measurements from these two instruments will be helpful in isolating and evaluating the important related physical processes.

#### Synergistic Group S-6

This is an entire Earth Resources grouping of the Water Availability Forecasting, World Crop Survey, and Vegetation Stress and Analysis programs coupled with the Comm/Nav Data Compression experiment. One of the key facets of the Water Availability Forecasting program is the determination of soil moisture. Soil moisture is of primary importance in both vegetation stress and crop prediction. In addition, the World Crop Survey may locate areas of vegetation stress for study in that program. The Earth Resources mission requires high data rate sensors such as SAR, therefore the Data Compression experiment can be run in parallel as an operational demonstration while providing additional experiment data.

#### Synergistic Group S-7

The Urban, Range, and Timber Inventory Application Development Programs are all by their nature land area delimiting processes. Each may contribute data to regional land use inventories or may interact as far as delimiting common boundaries is concerned. Commonality of equipment is also present since a Modular Multispectral Scanner and a High Resolution Camera are the main sensors involved (Note: the Range Inventory may also require a SIMS). Schedules of coverage and spectral bands would have to be determined.

#### Synergistic Group S-8

Measurement data from the MWE mission (CN-1) will include RF attenuation in the 20 and 30 GHz bands, phase distortion caused by atmospheric (clouds, water, ice, etc.), and related atmospheric phenomena that would affect transmission of dual polarized signals. The Cloud Climatology mission (W&C-2) is designed to provide information on clouds, water vapor droplet size, ice, cloud density, etc. The composite make-up of the atmosphere through which RF energy is propagated, is known to have a large effect on the amount and type of distortion experienced by RF energy. Also, characteristics of certain types of cloud formations vary greatly throughout the formation. It follows that the benefit to be derived from the MWE and Cloud Climatology missions can be best derived by in-situ measurements of propagation through cloud formations and concurrently measuring composite data on the cloud formation.

#### Synergistic Group S-9

This synthesized payload will essentially result in an additional mission focused on the study of tropical storms. Measurement of water vapor, liquid water content, surface winds, sea surface temperature, developing wave fields, and water level should lead to better modeling and prediction of the growth and movement of storms, and the development of storm surges.